NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, D.C. 20594

GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION

On Board Video Recording

DCA11MA076

by

Douglass P. Brazy
Mechanical Engineer

Warning
The reader of this report is cautioned that the documentation of a video recording is not a precise science but is the best product possible from an NTSB group investigative effort. The transcript (or summary), or parts thereof, if taken out of context, could be misleading. The attached documentation should be viewed as an accident investigation tool to be used in conjunction with other evidence gathered during the investigation. Conclusions or interpretations should not be made using the transcript as the sole source of information.

NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, D.C. 20594

March 5, 2012

On Board Video Recording

Group Chairman's Factual Report
by Douglass P. Brazy

NTSB Accident Number
DCA11MA076

1. EVENT SUMMARY

Location:	Roswell, New Mexico
Date:	April 02, 2011
Aircraft:	Gulfstream Aerospace Corporation GVI (G650)
Registration:	N652GD
Operator:	Gulfstream Aerospace Corporation
NTSB Number:	DCA11MA076

On April 2, 2011, about 0934 mountain daylight time, an experimental Gulfstream Aerospace Corporation (GAC) GVI (G650)[1], registration N652GD, serial number 6002, crashed during takeoff from runway 21 at Roswell International Air Center Airport (ROW), Roswell, New Mexico. The flight was being operated by the manufacturer as part of its G650 developmental field performance flight test program. The two pilots and the two flight test engineers were fatally injured, and the airplane was substantially damaged. The flight was being conducted under 14 *Code of Federal Regulations* Part 91, and visual meteorological conditions prevailed at the time of the accident.

The airplane was equipped with an on-board video/audio system which included an internal cockpit camera with a view of the flight deck, and audio from the airplane's intercom system.

[1] Gulfstream uses the Roman numeral designation "GVI" for aircraft certification purposes and the designation "G650" for marketing purposes. These designations mean the same aircraft model for purposes of this report and are used interchangeably.

2. VIDEO RECORDER GROUP

A video recorder group was convened on April 19, 2011.

Chairman:	Douglass P. Brazy Mechanical Engineer National Transportation Safety Board
Member:	Tom Latson Air Safety Investigator National Transportation Safety Board
Member:	Mitch Gallo Air Safety Investigator Operational Factors Group Chairman National Transportation Safety Board
Member:	Bill Bramble Air Safety Investigator Human Factors Group Chairman National Transportation Safety Board
Member:	Jeff Borton Flight Test Pilot Wichita Aircraft Certification Office Federal Aviation Administration
Member:	T.R. Proven Air Safety Investigator Federal Aviation Administration
Member:	Harold R. Gaston Vice President – Flight Operations Gulfstream Aerospace Corporation
Member:	Thomas Horne Experimental Test Pilot Gulfstream Aerospace Corporation

3. DETAILS OF INVESTIGATION

3.1. Item(s) Received

On April 7, 2011 the Safety Board's Vehicle Recorder Division received a hard disk drive (Seagate 500 GB , model and serial numbers illegible) from an Epiphan model "VGA Recorder Pro" digital video recording (DVR) system. The disk drive was sooted from the post-crash fire, but otherwise undamaged.

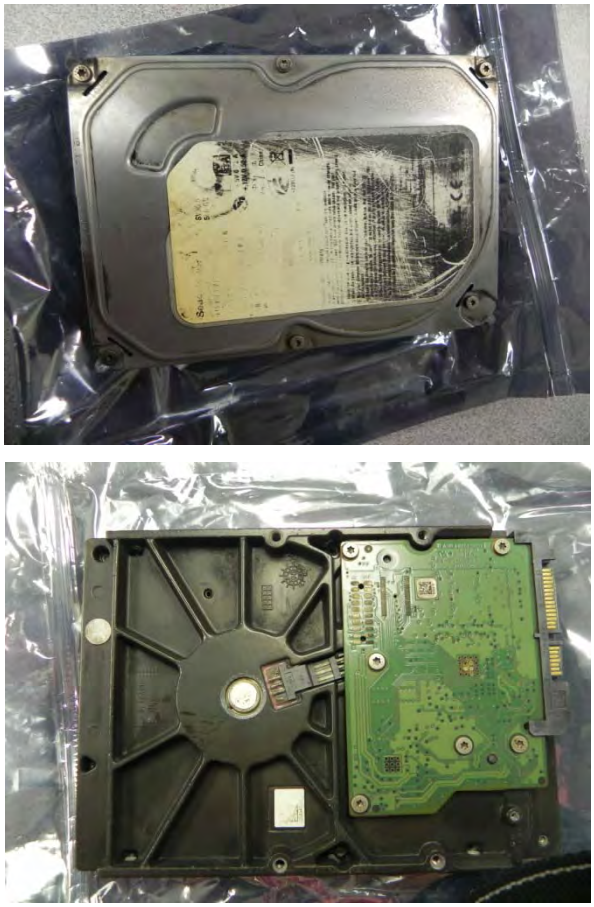


Figure 1 - Seagate Hard Disk Drive

3.2. Download and Recorder Details

The contents of the disk drive were downloaded using a laboratory computer station, normally, without difficulty. The data was found to be stored as a sequence of conventional audio-video-interleave (.avi) files which were accessible and viewable with typical Microsoft Windows operating system utilities. The .avi files contained both audio and video, were encoded with an MPEG-4 video codec, with an image size of 1280x720 and frame rate 30 frames per second (FPS). Each file contains about 04:11 (min:sec) of video/audio.

3.2.1. Video

The video captured by the DVR was from a single camera, mounted in the rear of the cockpit above the pilots' heads, with a forward looking view toward the instrument panel. The camera view was similar to the computer model rendition shown in Figure 2.

Figure 2 - Exemplar of Camera View[2]

[2] This is a computer model view of the G650 Cockpit, similar to the camera view from the DVR. Copyright 2009 Gulfstream Aerospace Corporation.

Most of the instrument panel was visible in the view, except that the right side Primary Flight Display (PFD), and right side control column were partially obscured by the second in command (SIC) pilot seated in the right seat. Only a small portion of the lower windscreen was in the view, and nothing was visible forward outside the airplane. The Heads Up Display (HUD) symbology was not visible, however a portion of the combining glass could be seen when the HUD was in the deployed position. None of the overhead or side panels were in the view. The pilots were visible when seated; the flight engineers could not be seen.

3.2.2. Audio

The audio portion of the recording captured sound/voice from the airplane's intercom system. All audio was captured through the pilots' and flight engineers' headset microphones, as well as from the aircraft radio system. The audio is consistent with at least one microphone being "hot" or on all the time, as opposed to being activated via a push to talk (PTT) configuration. A review of recordings from previous flights indicated that the flight engineers' microphones were configured for voice activated (VOX) communications. The recording captured onboard conversations between all flight crew, as well as ground communications, including those to and from a company telemetry trailer located at the test site(s).

3.2.3. Recording Duration and Timing – Accident Date

On the day of the accident, the on-board recording began at approximately 0630 Mountain Daylight Time (MDT) and ended at approximately 0934 MDT, on April 2, 2011. The test flight[3] for this day was identified as flight 153, which involved takeoff field performance testing. During this time, the airplane flew 11 complete test runs (takeoffs and landings) prior to the accident run. The recording ended prematurely during the accident test run, about 4 seconds after the Pilot-In-Command (PIC) pulled on the control column to initiate rotation of the airplane. The remainder of the flight was not captured.

[3] GAC nomenclature refers to a "Flight" as the time from engine start to engine shutdown. Several takeoffs and landings, or "test runs" can occur during a given "Flight".

The last .avi file in the sequence stored on the hard disk drive was partially corrupt. The duration of the recording in this file was approximately 36 seconds. This loss of data is most likely due to an abnormal shutdown (sudden loss of electrical power) which did not allow sufficient time for the system to finish processing the portions of the recording that were stored in buffers, prior to writing the data to the disk drive. This phenomenon is common with many digital video systems. A cursory examination of the contents of the last recorded .avi file revealed that a portion of the corrupt data included remnants from an earlier recording.

Each recording contained a "burned in" timecode visible in each frame of the video. This timecode is shown as text, in the lower left corner of the image. The time value was specified in (hours:minutes:seconds:milliseconds), and reflected the Greenwhich Mean Time (GMT) time zone.

On the day of the accident, the video timecode clock was found to be 4.98 seconds behind (slower) the clock used to timestamp parametric data captured by the on-board data recording/monitoring systems.[4] This 4.98 second difference was calculated for the accident day (flight 153) only. A review of the video recording timestamps during the wing drop events in flights 88 and 132 indicated a difference of 1 second or less.

Time values specified for the day of the accident have been converted to the local time zone (MDT).

3.3. Recordings from Previous Flights

The Operations Group Chairman for this investigation requested and received copies of video recordings from GAC, for several previous test flights of the accident airplane. These recordings were from selected previous flights which involved takeoff performance testing, and included two test runs during which a "wing drop" event occurred on takeoff. These flights were:

[4] For more information see the Data Recorders Group Chairman's Factual Report for this investigation.

Flight 081 - V_{MU} Development (Heavy)[5] – Roswell, NM, November 2010
(11 test runs)
Flight 083 - V_{MU} Development (Light) – Roswell, NM, November 2010
(7 test runs)
Flight 088 - V_{MU} Development (Medium) Roswell, NM, November 2010
(11 test runs, wing drop occurred during Test Card 2A)
Flight 111 - Takeoff Technique Development, Birmingham, AL, February 2011
(7 test runs)
Flight 132 – Takeoff Performance – One Engine Inoperative (OEI) , Roswell, NM,
March 2011, (4 test runs, wing drop occurred during Test Card 3B1)

The recordings from these previous flights were reviewed by the video group, along with the recording from the accident day, over the course of several months. A total of approximately 17 hours of video were examined.

3.4. Description of Attachments

Attachment I

Attachment I contains copies of the relevant test cards which document and outline the test conditions for each flight and test run.

Attachment II - Recording Summaries and Transcripts

Attachment II contains the video group's observations and summaries of the content of the recording, organized sequentially by flight number and in chronological order. Most of the observations were written as summaries, however conversations during the two test runs during which a wing drop occurred, were transcribed verbatim.[6]

[5] Attachment I contains copies of all the test cards which document and outline the test conditions for each flight and test run.
[6] The video recording of the test runs from the accident day including the accident run, were summarized by the Video Group. Verbatim transcripts from the accident run and the run immediately preceding it, were produced by the Cockpit Voice Recorder (CVR) Group. The audio from the CVR was nearly identical to the audio track from the

Each section in Attachment II begins with the flight number, followed by some general notes, and a listing of the flight crew for that particular flight. Next are excerpts from the relevant test cards from that flight, which generally describe the maneuvers documented in the following summary (or transcribed) text. Figure 3 provides an example of a flight number description, and excerpt from a test card.

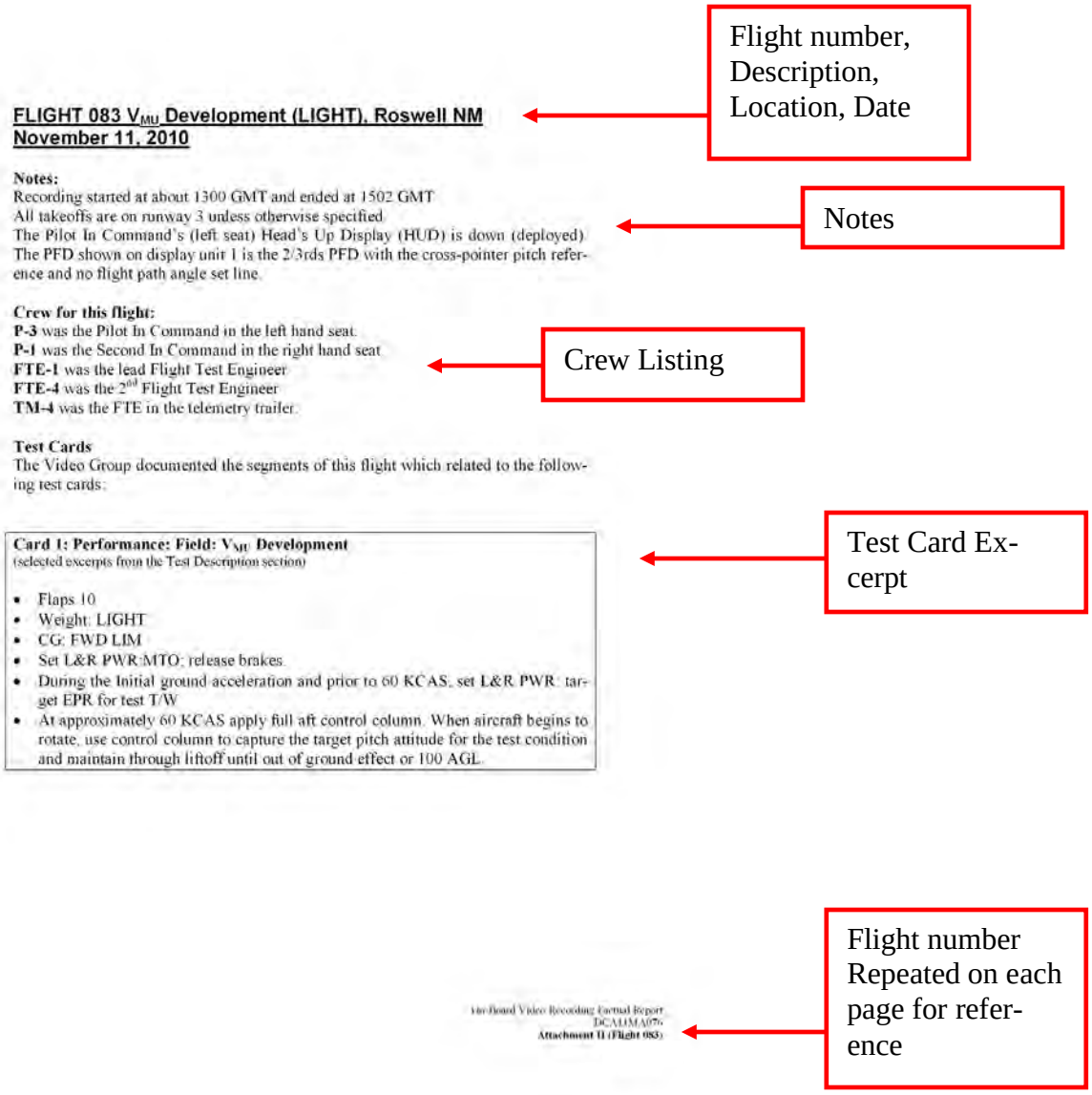


Figure 3 - Example of Description and Excerpt from Test Cards

video recording; however the CVR continued to record after the video recording had stopped. The CVR transcript can be found in the separate report entitled Cockpit Voice Recorder Group Chairman's Factual Report.

Within each flight, the summaries are organized by test run. The name of the test run appears in chronological order within the text, at approximately the time of takeoff for that run. Figure 4 is an example of a test run description from Attachment II.

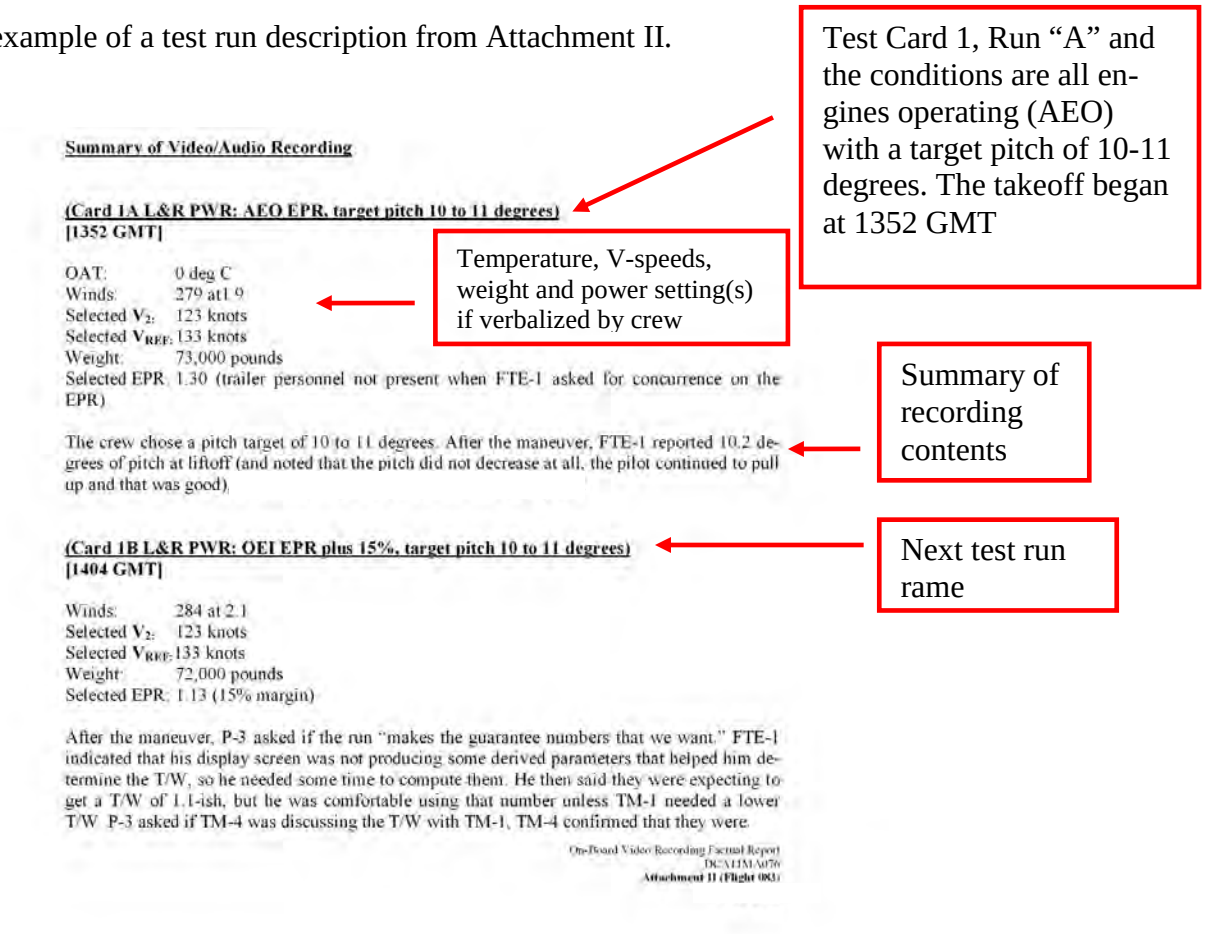


Figure 4 - Example of Test Run Description

Douglass P. Brazy

Mechanical Engineer
NTSB Vehicle Recorder Division

Attachment I – Test Cards

Gulfstream
A GENERAL DYNAMICS COMPANY

FLIGHT TEST CARDS

Reg. No. **N652GD** Serial No: **6002** Flight No: **081** Date: **10NOV2010**

ERO FUEL WEIGHT	[redacted]	TAKEOFF GROSS WEIGHT	[redacted]	FLAPS 10	FLEX [Rated] Rated
ZERO FUEL C.G.		TAKEOFF C.G.		V1 / VR 145/145	VSE 197
FUEL LOAD – LEFT		TOTAL FUEL		V2 155	VREF [redacted]
– RIGHT				FIELD 8600	TO TRIM

VHF TEST FREQUENCIES **SATCOM Number**

[redacted]

AIRCRAFT CONFIGURATION / TEST SUPPORT

[redacted]

LIMITATIONS / RESTRICTIONS

[redacted]

5. HUD combiner misaligned in pitch – use caution on landing
6. **USE OF NORMAL MODE PROHIBITED**

HAZARDS/TSHA's

TSHA-00083 Field Performance – VMU HIGH

EMERGENCY EQUIPMENT

1. Fire Extinguishers (3) & Fire Axe
2. First Aid Kit
3. Life raft
4. O2 Walkaround Bottles

DATA SYSTEMS

[redacted]

PURPOSE OF TEST:

1. Heavy weight Minimum Unstick Speed

6002 Call in: [redacted]

CREW:

1. Jake Howard
2. Kent Crenshaw
3. Valerie Thurston ←
4. Reece Ollenburg

		Go Around's	
		Full Stop	11
ENG START	/	Touch & Go's	
ENG SHUT DOWN	/	Total Landings	11
CHOCKS IN	1554	LANDING	1546
TAXI	1324	TAKEOFF	1338
BLOCK TIME	2+30	TOTAL FLIGHT	2+8

Aircraft Configuration Release

FTE Configuration Acceptance

[redacted]

Model:	[redacted]	6002 Flight 081	Card:	1

Performance: Field
Vmu Development

SET UP		NOTES		NOTES
FLAPS:	20	CG	FWD LIM	
GEAR:	EXT	L PWR	NOTED	
ALT:	0	R PWR	NOTED	
A/S:	0	Bleed	ECS	
Weight	HEAVY	PITCH	NOTED	

RUN **TEST DESCRIPTION**

25.107

[redacted]

1. Configure aircraft for takeoff.
2. Align aircraft on runway and apply brakes.
3. Set L & R PWR: MTO; release brakes.
4. During the initial ground acceleration and prior to 60 KCAS, set L & R PWR: target EPR for test T/W.
5. At approximate 80 KCAS apply full aft control column. When aircraft begins to rotate, use control column to capture the target pitch attitude for the test condition and maintain through liftoff until out of ground effect or 100 ft AGL.
6. If target liftoff attitude is achieved, perform next pitch attitude.
7. If final pitch is achieved, perform next test condition.

Note: Some additional nose-up trim may be used if insufficient elevator power to obtain target conditions before liftoff.

A ✓ 93-311.1 HIGH RISK PITCH:7 to 8 [redacted]
L & R PWR: two eng min T/W plus

B ✓✓ 93-311.1 HIGH RISK PITCH:7 to 8
L & R PWR: two eng min T/W

C ✓ 93-311.2 HIGH RISK PITCH:8 to 9
L & R PWR: two eng min T/W

D ✓ 93-311.3 HIGH RISK PITCH:9 to 10
L & R PWR: two eng min T/W

E ✓ 93-311.4 HIGH RISK PITCH:9 to 10
L & R PWR: single eng min T/W plus (optional)

F 93-311.4 HIGH RISK PITCH:9 to 10
L & R PWR: single eng min T/W

<>

TIME	NOTES
	α_{lim} = 12.6° (96% norm AoA) $\alpha_{85\%}$ = 11°
	α_{shaker} = 12.8° (97% norm. AoA) α_{SR} = 13.2 α_S = [redacted]
	Config 1 for Max Alt gains

Model:		6002 Flight 081	Card:	2

Performance: Field
Vmu Development

SET UP		NOTES		NOTES
FLAPS:	10	CG	FWD LIM	
GEAR:	EXT	L PWR	NOTED	
ALT:	0	R PWR	NOTED	
A/S:	0	Bleed	ECS	
Weight	HEAVY	PITCH	NOTED	

RUN **TEST DESCRIPTION**

25.107

[redacted]

1. Configure aircraft for takeoff.
2. Align aircraft on runway and apply brakes.
3. Set L & R PWR: MTO; release brakes.
4. During the initial ground acceleration and prior to 60 KCAS, set L & R PWR: target EPR for test T/W.
5. At aproximate 60 KCAS apply full aft control column. When aircraft begins to rotate, use control column to capture the target pitch attitude for the test condition and maintain through liftoff until out of ground effect or 100 ft AGL.
6. If target liftoff attitude is achieved, perform next pitch attitude.
7. If final pitch is achieved, perform next test condition.

Note: Some additional nose-up trim may be used if insufficient elevator power to obtain target conditions before liftoff. If additional trim is insufficient move to the AFT CG configuration.

A ✓ 93-311.13 HIGH RISK PITCH:8 to 9
L & R PWR: two eng min T/W plus

B 93-311.13 HIGH RISK PITCH:8 to 9
L & R PWR: two eng min T/W

C ✓ 93-311.14 HIGH RISK PITCH:9 to 10
L & R PWR: two eng min T/W

D ✓ 93-311.15 HIGH RISK PITCH:10 to 11
L & R PWR: two eng min T/W

E 93-311.16 HIGH RISK PITCH:10 to 11
L & R PWR: single eng min T/W plus (optional

F ✓✓ 93-311.16 HIGH RISK PITCH:10 to 11
L & R PWR: single eng min T/W

<>

TIME **NOTES**

α_s = [redacted] α_{SR} = 13.8° α_{lim} = 13.2°
α_{shaker} = 11.7°

Model:	(	6002 Flight 081	Card:	3	TIME	NOTES
		Landing				

[redacted]

:	TSHA-000083	Field Performance - VMU	
Risk:	High	Probability:	Low

Test Applicability:

93 - 311	Performance: Field: Vmu Development
93 - 312	Performance: Field: Vmu: Vmu Certificaton
93 - 313	Performance: Field: Vmu: Vmu Assurance

Hazard: Aircraft Departs Runway/Inadvertent Ground Contact

Cause: Excessive rotation force/over rotation at low airspeed, low altitude stall, loss of an engine at low T/W conditions

Effect: Loss of aircraft/loss of crew.

Preventative Actions / Minimizing Procedures:

1. All testing shall be conducted under day VMC conditions on a smooth, hard-surfaced dry runway. Tests shall be conducted at KROW on Runway 3/21 which is 13000'x300' or KVQQ on Runway 18L/36R which is 12503'x197'.
2. Brief local fire and rescue crews on test conditions.
3. Service struts, brakes and tires to recommended limits.
4. Only crewmembers deemed essential for conduct of the test shall be onboard.
5. Testing will be conducted while winds at the runway are below 5 knots from any direction and not gusting.
6. Alpha limiter will remain OFF during the testing.
7. Alternate control law maximum gains will be loaded prior to testing.
8. OEI testing will be conducted by simulating the OEI condition, using the equivalent OEI total thrust divided between both operating engines.
9. VMU testing will be approached in a build-up manner. Testing will begin at AEO high T/W conditions and proceed to the lower T/W conditions required. The number of required build-ups and repeat testing will be determined by the on-site test team.
10. Pitch attitude limit will be based on the build up testing, and will maintain an in-ground-effect AOA margin similar to the free air AOA limiter margin (not less than 1.5 degrees).
11. Do not allow airplane roll angle to exceed 5 degrees. Wing tip TE strike is estimated to occur around 5 degrees of roll attitude for the expected maximum Vmu attitude.
12. Cool brakes as required between test points. Periodically visually inspect brakes and tires and check tire temperatures to maintain below 150 degF.

Corrective Techniques:

1. If the aircraft is airborne and an engine fails, decrease pitch attitude, establish a stable bank angle, and advance the operative engine PLA so the aircraft will accelerate and then climb to desired altitude. Minimize asymmetric thrust if possible. Make turns into the operating engine and climb at no less than V2 to safe altitude.
2. If the aircraft is over-rotated, or rotated early and stalls, decrease pitch attitude, maintain wings level, advance PLA on both engines, accelerate and then climb to desired altitude.

[redacted] Engineer: [redacted] Test Conductor/Coordinator: [redacted]

Pilot: [redacted] Manager: [redacted]

Gulfstream
A GENERAL DYNAMICS COMPANY

FLIGHT TEST CARDS

Reg. No. **N652GD** Serial No: **6002** Flight No: **083** Date: **11NOV2010**

~~ZERO~~ FUEL WEIGHT	[redacted]	TAKEOFF GROSS WEIGHT	[redacted]	FLAPS	~~25~~ 10
ZERO FUEL C.G.	[redacted]	TAKEOFF C.G.	[redacted]	V1 / VR	~~120/124~~ 109/112
FUEL LOAD – LEFT	[redacted]	TOTAL FUEL	[redacted]	V2	~~130~~ 124
– RIGHT	[redacted]		16.4	FIELD	~~6970~~ 4439

FLEX [Rated]	Rated
VSE	~~170~~ 167
VREF	[redacted]
TO TRIM	[redacted]

VHF TEST FREQUENCIES **SATCOM Number**
123.57 **123.15** ~~**123.20**~~

AIRCRAFT CONFIGURATION / TEST SUPPORT

[redacted]

LIMITATIONS / RESTRICTIONS

1. [redacted]
2.
3.
4.
5.
6. **USE OF NORMAL MODE PROHIBITED**

HAZARDS/TSHA's
TSHA-00083 Field Performance – VMU HIGH

EMERGENCY EQUIPMENT

1. Fire Extinguishers (3) & Fire Axe
2. First Aid Kit
3. Life raft
4. O2 Walkaround Bottles

DATA SYSTEMS

[redacted]

PURPOSE OF TEST:

1. Light Weight Minimum Unstick Speed

6002 Call in [redacted]

CREW:

1. Jake Howard
2. Kent Crenshaw
3. Valerie Thurston
4. Reece Ollenburg

		Go Around's	
		Full Stop	6
ENG START	1339 / 1338	Touch & Go's	
ENG SHUT DOWN	1459 / 1459	Total Landings	6
CHOCKS IN	1459	LANDING	14:46
TAXI	1345	TAKEOFF	1353
BLOCK TIME	1+14	TOTAL FLIGHT	~~+57~~ +53

Aircraft Configuration Release

FTE Configuration Acceptance [redacted]

Model:		6002 Flight 083	Card: 1

Performance: Field
Vmu Development

SET UP		NOTES		NOTES
FLAPS:	10	CG	FWD LIM	
GEAR:	EXT	L PWR	NOTED	
ALT:	0	R PWR	NOTED	
A/S:	0	Bleed	ECS	
Weight	~~HEAVY~~ LIGHT	PITCH	NOTED	

RUN	TEST DESCRIPTION

25.107

1. Configure aircraft for takeoff.
2. Align aircraft on runway and apply brakes.
3. Set L & R PWR: MTO; release brakes.
4. During the initial ground acceleration and prior to ~~60~~ 50 KCAS, set L & R PWR: target EPR for test T/W.
5. At aproximate ~~60~~ 50 KCAS apply full aft control column. When aircraft begins to rotate, use control column to capture the target pitch attitude for the test condition and maintain through liftoff until out of ground effect or 100 ft AGL.
6. If target liftoff attitude is achieved, perform next pitch attitude.
7. If final pitch is achieved, perform next test condition.

Note: Some additional nose-up trim may be used if insufficient elevator power to obtain target conditions before liftoff. If additional trim is insufficient move to the AFT CG configuration.

A 93-311.13 HIGH RISK PITCH:10 to 11
L & R PWR: AEO EPR Pull pwr back @ 60 kts

B 93-311.13 HIGH RISK PITCH:10 to 11
L & R PWR: OEI EPR plus 15%

C 93-311.14 HIGH RISK PITCH:10 to 11
L & R PWR: OEI EPR

<>

$V_{LO} \approx 115$

TIME	NOTES

Model:	6002 Flight 083	Card: 4 2

Performance: Field
Vmu Development

SET UP		NOTES		NOTES
FLAPS:	20	CG	FWD LIM	
GEAR:	EXT	L PWR	NOTED	
ALT:	0	R PWR	NOTED	
A/S:	0	Bleed	ECS	
Weight	~~HEAVY~~ LIGHT	PITCH	NOTED	

RUN	TEST DESCRIPTION
	25.107 1. Configure aircraft for takeoff. 2. Align aircraft on runway and apply brakes. 3. Set L & R PWR: MTO; release brakes. 4. During the initial ground acceleration and prior to ~~60~~ 80 KCAS, set L & R PWR: target EPR for test T/W. 5. At approximate ~~60~~ 80 KCAS apply full aft control column. When aircraft begins to rotate, use control column to capture the target pitch attitude for the test condition and maintain through liftoff until out of ground effect or 100 ft AGL. 6. If target liftoff attitude is achieved, perform next pitch attitude. 7. If final pitch is achieved, perform next test condition. Note: Some additional nose-up trim may be used if insufficient elevator power to obtain target conditions before liftoff.
A	93-311.5 HIGH RISK PITCH:9 to 10 L & R PWR: AEO EPR pull back Eng @ 60 kts
B	93-311.6 HIGH RISK PITCH:9 to 10 L & R PWR: OEI EPR plus 15%
C	93-311.6 HIGH RISK PITCH:9 to 10 L & R PWR: OEI EPR $V_{LO} \approx$ 108-112 +15
<>	

TIME	NOTES

Model:		6002 Flight 083	Card:	3

Landing

[redacted]

TIME	NOTES

GVI Level Flight Weight/CG Envelope

GULFSTREAM AEROSPACE CORPORATION
AIRCRAFT WEIGHT AND BALANCE CALCULATION

DATE	25-Oct-10
MODEL:	GVI
SERIAL NO:	SN6002
REGISTRATION:	N652GD
FLIGHT:	083

	WEIGHT	ARM	MOMENT	% MAC
Form A Weight (8-28-10)	[redacted]			[redacted]
Pilot				
Co-Pilot				
Jumpseat				
FTI/STI workstation				
L FTE workstation				
R FTE Workstation				
EMS Workstation				
AV Workstation				
Entryway Ballast				

	WEIGHT	ARM	MOMENT	% MAC
ZERO FUEL GROSS WEIGHT	[redacted]			[redacted]
TOTAL FUEL LOAD				
RAMP GROSS WEIGHT				
START AND TAXI FUEL				
TAKEOFF FUEL LOAD				
TAKE-OFF GROSS WEIGHT				[redacted]

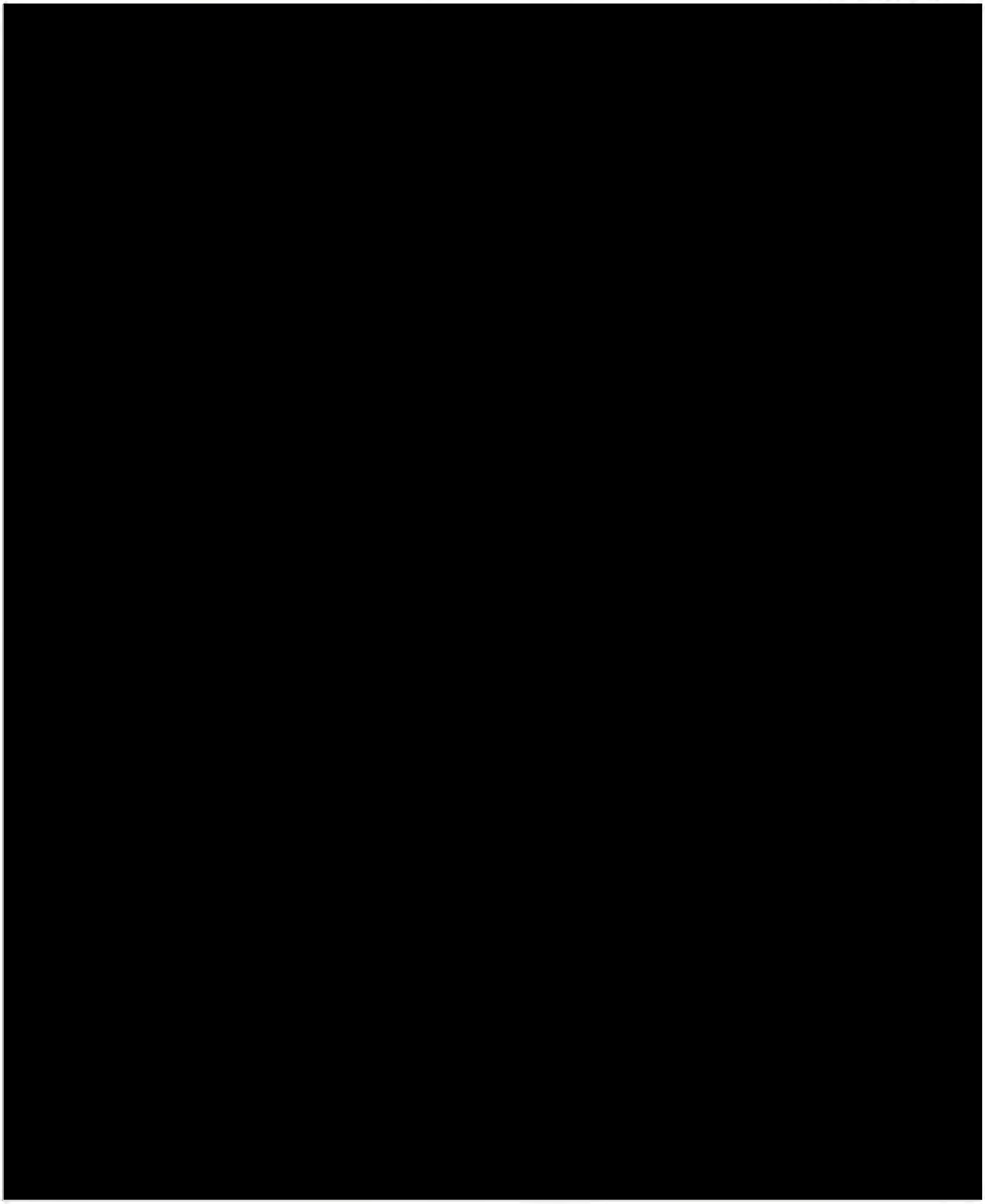
PREPARED BY:
11/10/2010 Franzel

TAKEOFF C.G. LIMITS	% MAC
FWD CG LIM =	[redacted]
AFT CG LIM =	

COMMENTS
Fwd CG [redacted] 2 FTE's
Crew: Howard, Crenshaw, Thurston, Ollenburg

[redacted]

11/10/2010



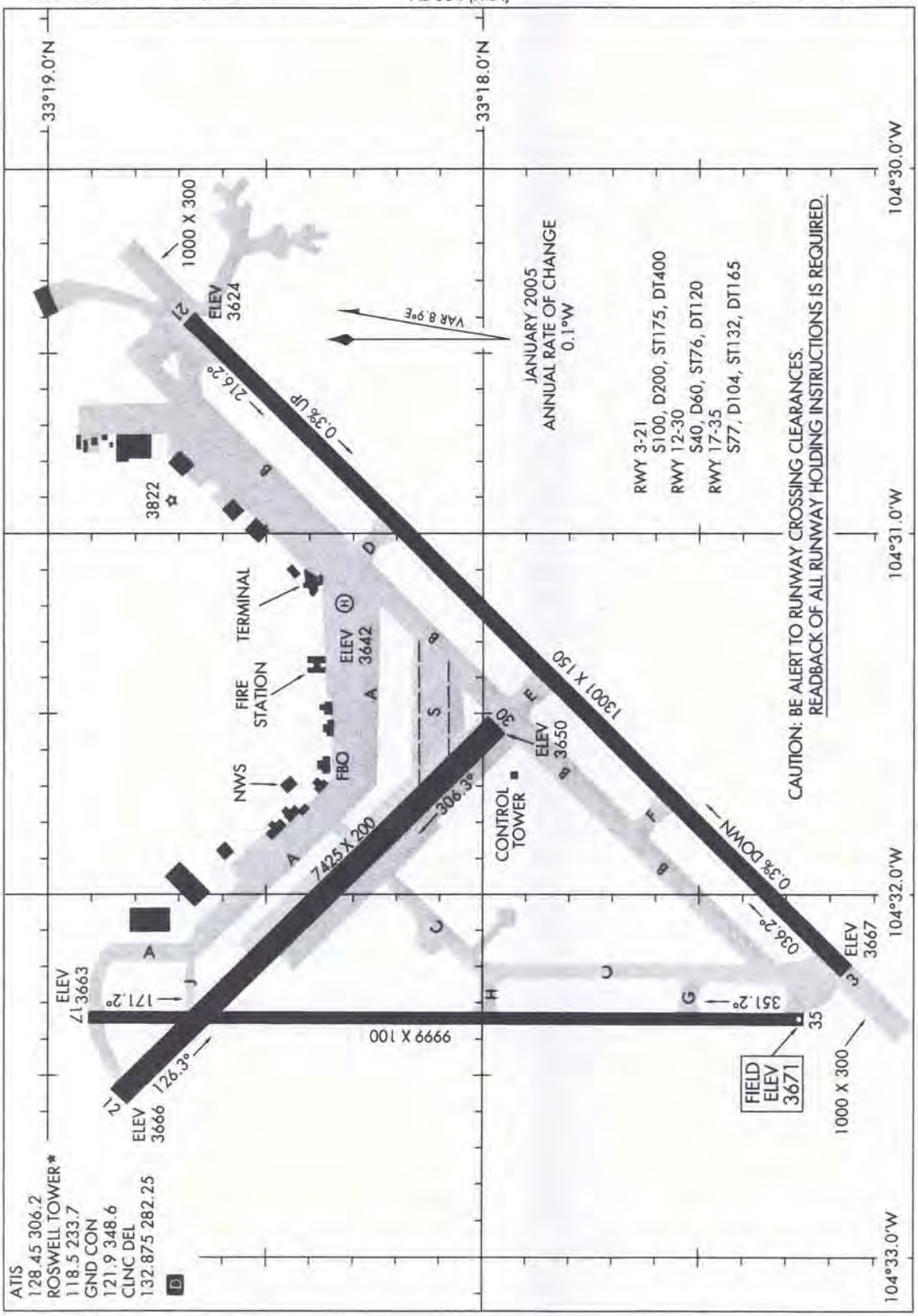
[redacted]

11/10/2010

AIRPORT DIAGRAM

AL-354 (FAA)

ROSWELL INTL AIR CENTER (ROW)
ROSWELL, NEW MEXICO



SW-1, 14 JAN 2010 to 11 FEB 2010

SW-1, 14 JAN 2010 to 11 FEB 2010

AIRPORT DIAGRAM
09295

ROSWELL, NEW MEXICO
ROSWELL INTL AIR CENTER (ROW)

[redacted]

ID:	TSHA-000083	Field Performance - VMU	
Risk:	High	Probability:	Low

Test Applicability:

93 - 311	Performance: Field: Vmu Development
93 - 312	Performance: Field: Vmu: Vmu Certificaton
93 - 313	Performance: Field: Vmu: Vmu Assurance

Hazard: Aircraft Departs Runway/Inadvertent Ground Contact

Cause: Excessive rotation force/over rotation at low airspeed, low altitude stall, loss of an engine at low T/W conditions

Effect: Loss of aircraft/loss of crew.

Preventative Actions / Minimizing Procedures:

1. All testing shall be conducted under day VMC conditions on a smooth, hard-surfaced dry runway. Tests shall be conducted at KROW on Runway 3/21 which is 13000'x300' or KVQQ on Runway 18L/36R which is 12503'x197'.
2. Brief local fire and rescue crews on test conditions.
3. Service struts, brakes and tires to recommended limits.
4. Only crewmembers deemed essential for conduct of the test shall be onboard.
5. Testing will be conducted while winds at the runway are below 5 knots from any direction and not gusting.
6. Alpha limiter will remain OFF during the testing.
7. Alternate control law maximum gains will be loaded prior to testing.
8. OEI testing will be conducted by simulating the OEI condition, using the equivalent OEI total thrust divided between both operating engines.
9. VMU testing will be approached in a build-up manner. Testing will begin at AEO high T/W conditions and proceed to the lower T/W conditions required. The number of required build-ups and repeat testing will be determined by the on-site test team.
10. Pitch attitude limit will be based on the build up testing, and will maintain an in-ground-effect AOA margin similar to the free air AOA limiter margin (not less than 1.5 degrees).
11. Do not allow airplane roll angle to exceed 5 degrees. Wing tip TE strike is estimated to occur around 5 degrees of roll attitude for the expected maximum Vmu attitude.
12. Cool brakes as required between test points. Periodically visually inspect brakes and tires and check tire temperatures to maintain below 150 degF.

Corrective Techniques:

1. If the aircraft is airborne and an engine fails, decrease pitch attitude, establish a stable bank angle, and advance the operative engine PLA so the aircraft will accelerate and then climb to desired altitude. Minimize asymmetric thrust if possible. Make turns into the operating engine and climb at no less than V2 to safe altitude.
2. If the aircraft is over-rotated, or rotated early and stalls, decrease pitch attitude, maintain wings level, advance PLA on both engines, accelerate and then climb to desired altitude.

Cog Engineer: [redacted] Test Conductor/Coordinator: [redacted]

Pilot: [redacted] Manager: [redacted]

Gulfstream
A GENERAL DYNAMICS COMPANY

FLIGHT TEST CARDS

Reg. No. **N652GD** Serial No: **6002** Flight No: **088** Date: **16NOV2010**

ERO FUEL WEIGHT	[redacted]	TAKEOFF GROSS WEIGHT	[redacted]	FLAPS	20	FLEX [Rated]	Rated
ZERO FUEL C.G.		TAKEOFF C.G.		V1 / VR	110/117	VSE	160
FUEL LOAD – LEFT		TOTAL FUEL		V2	123	VREF	[redacted]
– RIGHT				FIELD	3992	TO TRIM	

VHF TEST FREQUENCIES **SATCOM Number**

[redacted]

AIRCRAFT CONFIGURATION / TEST SUPPORT

[redacted]

LIMITATIONS / RESTRICTIONS

[redacted]

5. HUD combiner misaligned in pitch – use caution on landing
6. **USE OF NORMAL MODE PROHIBITED**

HAZARDS/TSHA's

TSHA-00084 - High - Field Performance – Takeoff
TSHA-00083 - High - Field Performance – VMU

EMERGENCY EQUIPMENT

1. Fire Extinguishers (3) & Fire Axe
2. First Aid Kit
3. Life raft
4. O2 Walkaround Bottles

DATA SYSTEMS

[redacted]

PURPOSE OF TEST:

1. 93-322 Takeoff
2. 93-361 Landing

CREW:

1. Jake Howard
2. Kent Crenshaw
3. Valerie Thurston
4. Reece Ollenburg

		Go Around's	
		Full Stop	12
ENG START	1318 / 1316	Touch & Go's	3
ENG SHUT DOWN	1525 / 1525	Total Landings	~~12~~ 15
CHOCKS IN	15.25	LANDING	15:20
TAXI	13.22	TAKEOFF	13:29
BLOCK TIME	2+3	TOTAL FLIGHT	1+51

Aircraft Configuration Release

FTE Configuration Acceptance

[redacted] Recording Factual Report

GVI Level Flight Weight/CG Envelope

GULFSTREAM AEROSPACE CORPORATION
AIRCRAFT WEIGHT AND BALANCE CALCULATION

DATE	16-Nov-10
MODEL:	GVI
SERIAL NO:	SN6002
REGISTRATION:	N652GD
FLIGHT:	088

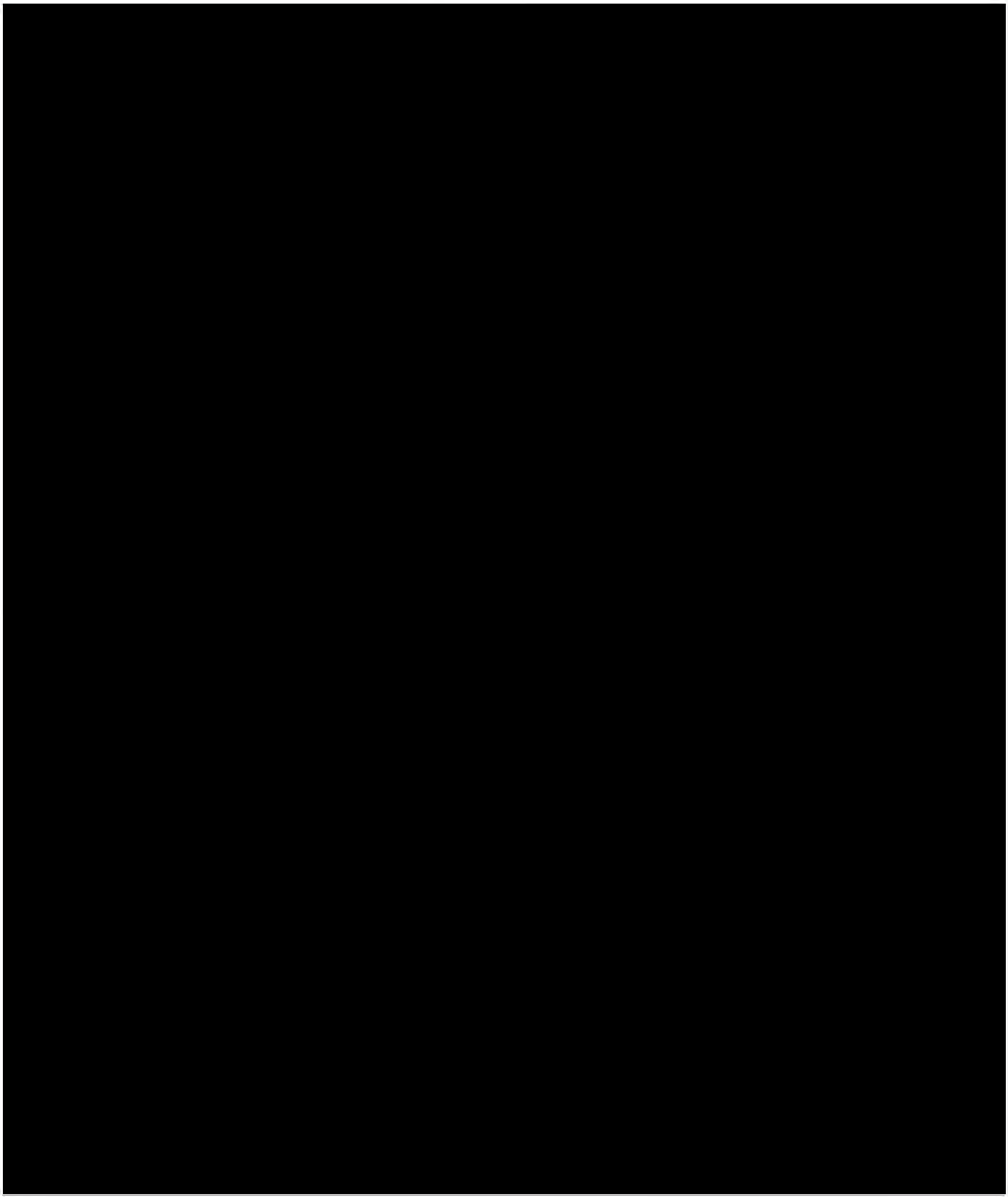
	WEIGHT	ARM	MOMENT	% MAC
Form A Weight (8-28-10)		[redacted]		[redacted]
Pilot				
Co-Pilot				
Jumpseat				
FTI/STI workstation				
L FTE workstation				
R FTE Workstation				
EMS Workstation				
AV Workstation				
Entryway Ballast				

	WEIGHT	ARM	MOMENT	% MAC
ZERO FUEL GROSS WEIGHT		[redacted]		[redacted]
TOTAL FUEL LOAD				
RAMP GROSS WEIGHT				
START AND TAXI FUEL				
TAKEOFF FUEL LOAD				
TAKE-OFF GROSS WEIGHT				[redacted]

PREPARED BY:
11/15/2010
Franzel

TAKEOFF C.G. LIMITS	% MAC
FWD CG LIM =	[redacted]
AFT CG LIM =	

COMMENTS
Fwd CG [redacted] 2 FTE's
Crew: Howard, Crenshaw, Thurston, Donovan



Model:	C	6002 Flight 088	Card:	2

Performance: Field
Vmu Development

SET UP		NOTES		NOTES
FLAPS:	20	CG	FWD LIM	
GEAR:	EXT	L PWR	NOTED	
ALT:	0	R PWR	NOTED	
A/S:	0	Bleed	ECS	
Weight	MEDIUM	PITCH	NOTED	

RUN	TEST DESCRIPTION
	25.107 1. Configure aircraft for takeoff. 2. Align aircraft on runway and apply brakes. 3. Set L & R PWR: MTO; release brakes. 4. During the initial ground acceleration and prior to 60 KCAS, set L & R PWR: target EPR for test T/W. 5. At aproximate 60 KCAS apply full aft control column. When aircraft begins to rotate, use control column to capture the target pitch attitude for the test condition and maintain through liftoff until out of ground effect or 100 ft AGL. 6. If target liftoff attitude is achieved, perform next pitch attitude. 7. If final pitch is achieved, perform next test condition. Note: Some additional nose-up trim may be used if insufficient elevator power to obtain target conditions before liftoff. If additional trim is insufficient move to the AFT CG configuration.
A	93-311.5 HIGH RISK PITCH: 9 to 10 L & R PWR: AEO EPR
<>	

TIME

NOTES

F20
V1 107 V1 113 V2 119

[redacted]

EPR = 1.33

[redacted]

[redacted]

Model: C	6002 Flight 088	Card: 3

Performance: Field: Takeoff
Pitch Attitude Development AEO

SET UP		NOTES		NOTES
FLAPS:	20	CG	FWD LIM	
GEAR:	EXT	L PWR	MTO	
ALT:	FIELD	R PWR	MTO	
A/S:	0	Bleed	ECS	
Weight	LIGHT	PITCH	NOTED	

RUN	TEST DESCRIPTION
	25.101, 25.105, 25.107
	1. Configure aircraft for takeoff with/except: as specified
	2. Align aircraft on runway and apply brakes
	3. Set L & R PWR: as specified; release brakes
	4. Rotate at VR at a normal rotation rate (3-5 degs/sec) to target pitch attitude.
	5. Maintain target pitch attitude until V2+10 is achieved.
	6. Retract gear after positive ROC is established.
	7. Adjust pitch attitude to maintain V2+10 to gear retraction or 400 ft AGL.
A	93-322.7 MEDIUM RISK PITCH:8 to 9
B	93-322.8 MEDIUM RISK PITCH:9 to 10
C	93-322.9 MEDIUM RISK PITCH:10 to 11
<>	

TIME *NOTES*

[redacted]

Model:	Gvi	6002 Flight 088	Card:	4

Performance: Field: Takeoff
Pitch Attitude Development OEI

SET UP		NOTES		NOTES
FLAPS:	20	CG	FWD LIM	~~R HYD SHUTOFF <~~
GEAR:	EXT	L PWR	NOTED	~~NOTED~~
ALT:	FIELD	R PWR	NOTED	
A/S:	0	Bleed	ECS	
Weight	LIGHT	PITCH	NOTED	

RUN	TEST DESCRIPTION
	25.101, 25.105, 25.107
	1. Configure aircraft for takeoff with/except: as specified
	2. Align aircraft on runway and apply brakes
	3. Set L & R PWR: MTO; release brakes; ~~R HYD SHUTOFF: ON~~
	4. At target VEF (V1 - ____), fail RH engine using a throttle chop. a. Use rudder and NWS control as required for directional control
	5. Rotate at VR at a normal rotation rate (3-5 degs/sec) to target pitch attitude.
	6. Maintain target pitch attitude until V2 is achieved.
	7. Retract gear after positive ROC is established.
	8. Adjust pitch attitude to maintain V2 to gear retraction or 400 ft AGL.
A	93-322.10 MEDIUM RISK PITCH:6 to 7
B	93-322.11 MEDIUM RISK PITCH:7 to 8
C	93-322.12 MEDIUM RISK PITCH:8 to 9
<>	

TIME	NOTES

[redacted]

Model:	C	6002 Flight 088	Card:	5

TIME NOTES

Performance: Field: Takeoff
Pitch Attitude Development AEO

SET UP		NOTES		NOTES
FLAPS:	10	CG	FWD LIM	R HYD SHUTOFF
GEAR:	EXT	L PWR	MTO	NOTED
ALT:	FIELD	R PWR	MTO	
A/S:	0	Bleed	ECS	
Weight	LIGHT	PITCH	NOTED	

RUN	TEST DESCRIPTION
	25.101, 25.105, 25.107
	1. Configure aircraft for takeoff with/except: as specified
	2. Align aircraft on runway and apply brakes
	3. Set L & R PWR: as specified; release brakes
	4. Rotate at VR at a normal rotation rate (3-5 degs/sec) to target pitch attitude.
	5. Maintain target pitch attitude until V2+10 is achieved.
	6. Retract gear after positive ROC is established.
	7. Adjust pitch attitude to maintain V2+10 to gear retraction or 400 ft AGL.
A	93-322.19 MEDIUM RISK PITCH:9 to 10
B	93-322.20 MEDIUM RISK PITCH:10 to 11
C	93-322.21 MEDIUM RISK PITCH:11 to 12
<>	

[redacted]

Model:	(	6002 Flight 088	Card:	6

TIME NOTES

Performance: Field: Takeoff
Pitch Attitude Development OEI

SET UP		NOTES		NOTES	
FLAPS:	10	CG	FWD LIM	R HYD SHUTOFF	
GEAR:	EXT	L PWR	NOTED		NOTED
ALT:	FIELD	R PWR	NOTED		
A/S:	0	Bleed	ECS		
Weight	LIGHT	PITCH	NOTED		

RUN	TEST DESCRIPTION
	25.101, 25.105, 25.107
	1. Configure aircraft for takeoff with/except: as specified
	2. Align aircraft on runway and apply brakes
	3. Set L & R PWR: MTO; release brakes: R HYD SHUTOFF: ON
	4. At target VEF (V1 - ___), fail RH engine using a throttle chop. a. Use rudder and NWS control as required for directional control
	5. Rotate at VR at a normal rotation rate (3-5 degs/sec) to target pitch attitude.
	6. Maintain target pitch attitude until V2 is achieved.
	7. Retract gear after positive ROC is established.
	8. Adjust pitch attitude to maintain V2 to gear retraction or 400 ft AGL.
A	93-322.22 MEDIUM RISK PITCH:7 to 8
B	93-322.23 MEDIUM RISK PITCH:8 to 9
C	93-322.24 MEDIUM RISK PITCH:9 to 10
<>	

[redacted]

Model:	6002 Flight 088	Card:	7	TIME	NOTES
	Performance: Field: Landing				

[redacted]

Model:	G	6002 Flight 088	Card:	8	TIME	NOTES
		Landing				

[redacted]

ID:	TSHA-000083	Field Performance - VMU	
Risk:	High	**Probability:**	Low

Test Applicability:

93 - 311	Performance: Field: Vmu Development
93 - 312	Performance: Field: Vmu: Vmu Certificaton
93 - 313	Performance: Field: Vmu: Vmu Assurance

Hazard: Aircraft Departs Runway/Inadvertent Ground Contact

Cause: Excessive rotation force/over rotation at low airspeed, low altitude stall, loss of an engine at low T/W conditions

Effect: Loss of aircraft/loss of crew.

Preventative Actions / Minimizing Procedures:

1. All testing shall be conducted under day VMC conditions on a smooth, hard-surfaced dry runway. Tests shall be conducted at KROW on Runway 3/21 which is 13000'x300' or KVQQ on Runway 18L/36R which is 12503'x197'.
2. Brief local fire and rescue crews on test conditions.
3. Service struts, brakes and tires to recommended limits.
4. Only crewmembers deemed essential for conduct of the test shall be onboard.
5. Testing will be conducted while winds at the runway are below 5 knots from any direction and not gusting.
6. Alpha limiter will remain OFF during the testing.
7. Alternate control law maximum gains will be loaded prior to testing.
8. OEI testing will be conducted by simulating the OEI condition, using the equivalent OEI total thrust divided between both operating engines.
9. VMU testing will be approached in a build-up manner. Testing will begin at AEO high T/W conditions and proceed to the lower T/W conditions required. The number of required build-ups and repeat testing will be determined by the on-site test team.
10. Pitch attitude limit will be based on the build up testing, and will maintain an in-ground-effect AOA margin similar to the free air AOA limiter margin [redacted]
12. Cool brakes as required between test points. Periodically visually inspect brakes and tires and check tire temperatures to maintain below 150 degF.

Corrective Techniques:

1. If the aircraft is airborne and an engine fails, decrease pitch attitude, establish a stable bank angle, and advance the operative engine PLA so the aircraft will accelerate and then climb to desired altitude. Minimize asymmetric thrust if possible. Make turns into the operating engine and climb at no less than V2 to safe altitude.
2. If the aircraft is over-rotated, or rotated early and stalls, decrease pitch attitude, maintain wings level, advance PLA on both engines, accelerate and then climb to desired altitude.

Cog Engineer: [redacted] **Test Conductor/Coordinator:** [redacted]

Pilot: [redacted] **Manager:** [redacted]

Gulfstream
A GENERAL DYNAMICS COMPANY

FLIGHT TEST CARDS

Reg. No. N652GD | Serial No: 6002 | Flight No: 111 | Date: 2/13/11

ZERO FUEL WEIGHT	[redacted]	TAKEOFF GROSS WEIGHT	[redacted]	FLAPS 20	FLEX [Rated] Rated
ZERO FUEL C.G.		TAKEOFF C.G.		V1 / VR 141/143	VSE 195
FUEL LOAD – LEFT		TOTAL FUEL		V2 149	VREF [redacted]
– RIGHT				FIELD 6621	TO TRIM

VHF TEST FREQUENCIES [redacted] **SATCOM Number**

AIRCRAFT CONFIGURATION / TEST SUPPORT

[redacted]

LIMITATIONS / RESTRICTIONS

[redacted]

5. HUD combiner misaligned in pitch – use caution on landing
6. Use pre-activation stall speed schedule for F0 Vref calculations per FS-AERO-10-033 RevA
7. FCS Normal Mode OK, Max Alt gains must be loaded for TO/landing

[redacted]

HAZARDS/TSHA's

TSHA-000084, Field Performance – Engine-out Takeoffs (OEI), RISK: HIGH

~~TSHA, Heavy Braking During Landings, RTOs and High Speed Taxi, RISK: HIGH~~

TSHA-000047, Single Engine Operations or Operation with a Single Hydraulic System, RISK: MEDIUM

EMERGENCY EQUIPMENT

1. Fire Extinguishers (3) & Fire Axe
2. First Aid Kit
3. Life raft
4. O2 Walkaround Bottles

DATA SYSTEMS

[redacted]

6002 Call in: [redacted]

PURPOSE OF TEST: DEVELOPMENT

Takeoff Technique Development

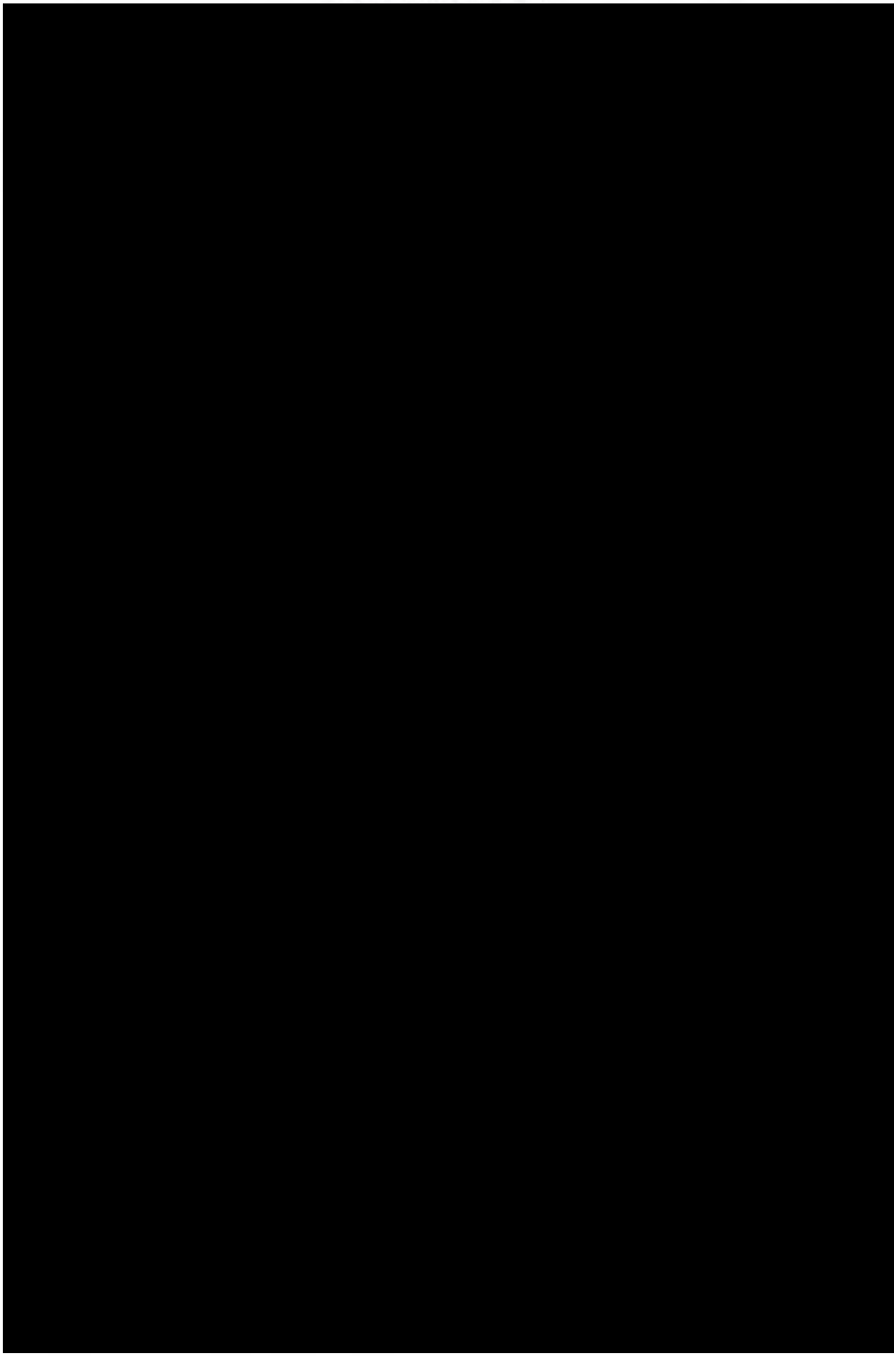
CREW:

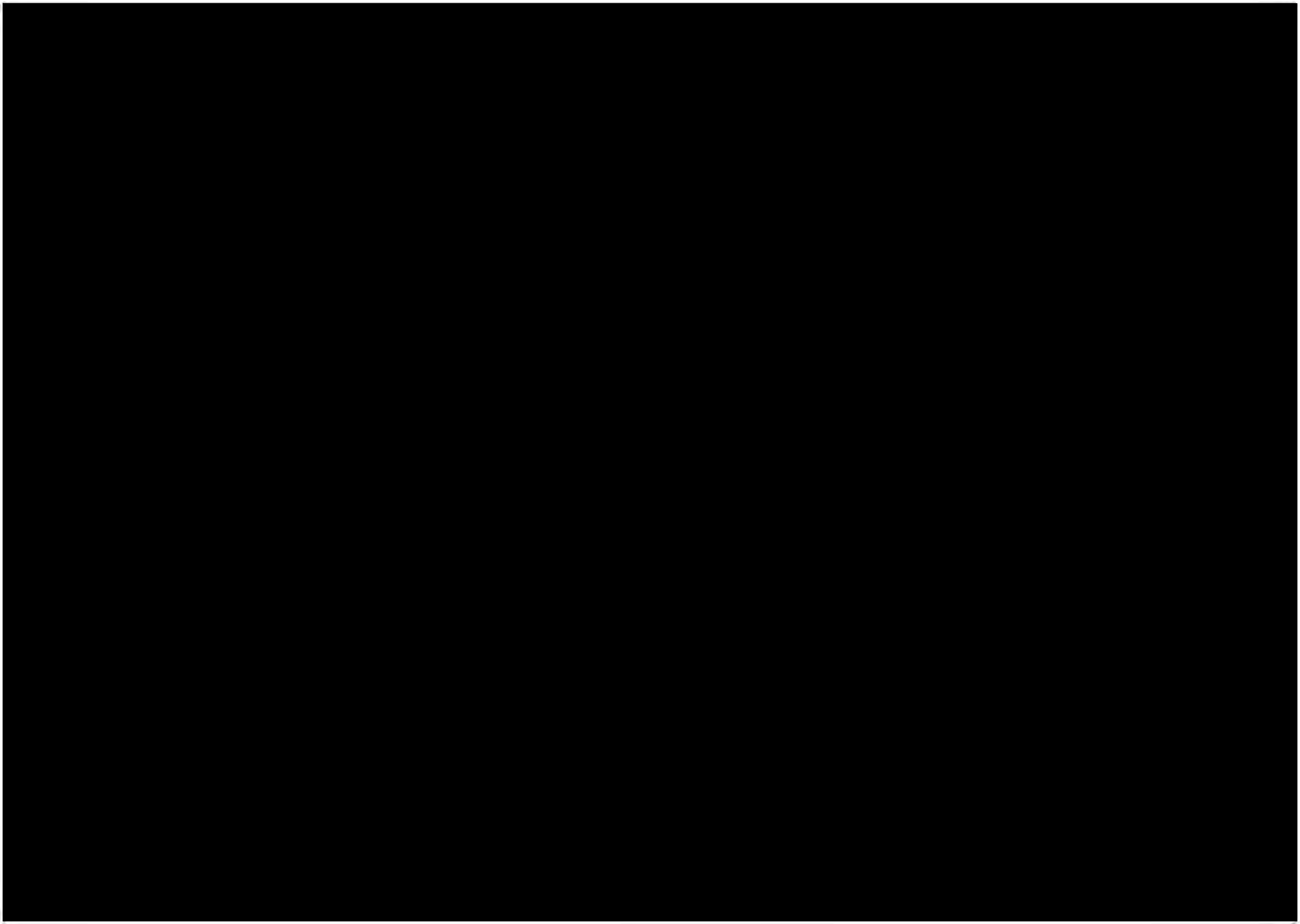
1. Jake Howard
2. ~~Kent Crenshaw~~ VIVAN RAGUSA
3. Reece Ollenburg
4. ~~Peter Hondy~~ VALERIE THURSTON

ENG START	1	Go Around's	
ENG SHUT DOWN	1	Full Stop	8
		Touch & Go's	
		Total Landings	8
CHOCKS IN	16:31	LANDING	16:29
TAXI	12:16	TAKEOFF	12:21
BLOCK TIME	4+15	TOTAL FLIGHT	4+08

Aircraft Configuration Release

FTE Configuration Acceptance





GVI Level Flight Weight/CG Envelope

GULFSTREAM AEROSPACE CORPORATION
AIRCRAFT WEIGHT AND BALANCE CALCULATION

DATE	13-Feb-11
MODEL:	GVI
SERIAL NO:	SN6002
REGISTRATION:	N652GD
FLIGHT:	111

	WEIGHT	ARM	MOMENT	% MAC
Form A Weight (12-19-10)	[redacted]			
Pilot				
Co-Pilot				
Jumpseat				
FTI/STI workstation				
L FTE workstation				
R FTE Workstation				
EMS Workstation				
AV Workstation				
Entryway Ballast				
L ferry crew seat				
L ferry crew seat				
L ferry crew seat				

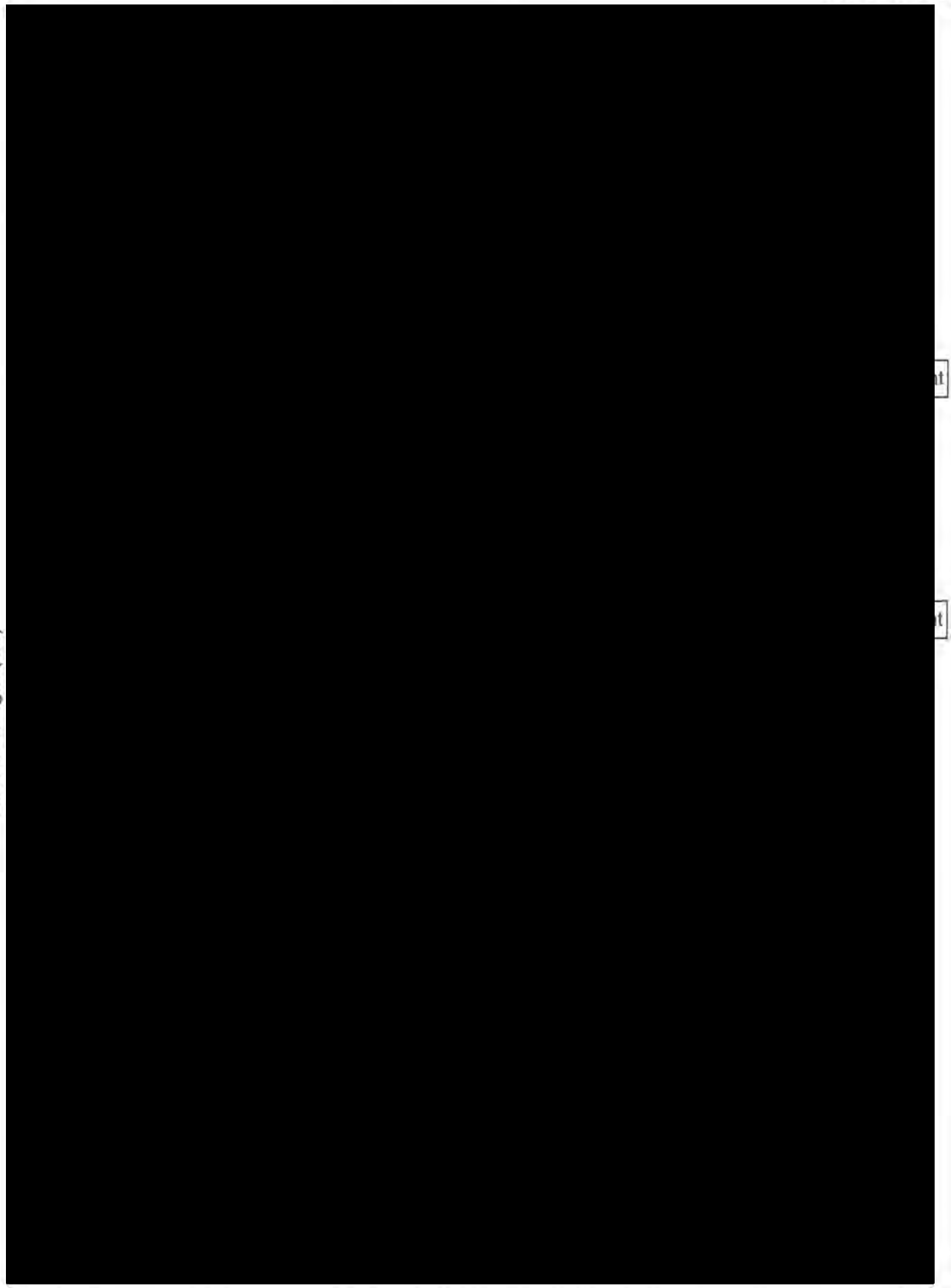
	WEIGHT	ARM	MOMENT	% MAC
ZERO FUEL GROSS WEIGHT	[redacted]			[redacted]
RAMP GROSS WEIGHT				
START AND TAXI FUEL				
TAKEOFF FUEL LOAD				
TAKE-OFF GROSS WEIGHT				[redacted]

PREPARED BY:
2/11/2011
Franzel

TAKEOFF C.G. LIMITS	% MAC
FWD CG LIM =	[redacted]
AFT CG LIM =	

COMMENTS
FLT 111, DV2.0 brakes testing
Crew: Ollenburg

[redacted]



[redacted]

Model:	GVI	6002 Flight 111	Card:	1
Power Up / Takeoff				

TIME

NOTES

[redacted]

Model:	GVI	6002 Flight 111	Card:	2
		Landing		

TIME

NOTES

[redacted]

Model:	GVI	6002 Flight 111	Card:	3

Performance: Field: Takeoff

Rotation Rate Development Low T/W

SET UP		NOTES		NOTES
FLAPS:	20	CG	FWD LIM	PITCH RATE NOTED
GEAR:	EXT	L PWR	MTO	
ALT:	FIELD	R PWR	MTO	
A/S:	NOTED	Bleed	ECS	
Weight	HEAVY	PITCH	NOTED	

RUN **TEST DESCRIPTION**

25.101, 25.105, 25.107

1. Configure aircraft for takeoff with/except: as specified

2. Align aircraft on runway and apply brakes

3. Set L & R PWR: MTO / MTO

4. At target VEF (V1 - 20), set L & R PWR: target EPR for test T/W

5. Rotate at VR at target rotation rate to 9 pitch attitude.

6. Maintain target pitch attitude until V2 is achieved.

7. Retract gear after positive rate-of-climb (ROC) is established.

8. Adjust pitch attitude to maintain V2 to gear retraction or 400 ft AGL.

Oversped stick force variation:

A 93-321.4 HIGH RISK STICK FRC: 45-55lb, VR + ~~6~~ 4

B 93-321.5 HIGH RISK STICK FRC: 55-65lb, VR + 6

C 93-321.6 HIGH RISK STICK FRC: 65-75lb, VR + 6

Speed variation:

D 93-321.6 HIGH RISK STICK FRC:____ , VR + 4

E 93-321.6 HIGH RISK STICK FRC:____ , VR + 2

F 93-321.6 HIGH RISK STICK FRC:____ , VR + 0

G 93-321.6 HIGH RISK STICK FRC:____ , VR - 2

Repeats:

H 93-321.6 HIGH RISK STICK FRC:____ , VR + __

I 93-321.6 HIGH RISK STICK FRC:____ , VR + __

<>

TIME ***NOTES***

Model:	GVI	6002 Flight 111	Card:	4
Performance: Field: Takeoff				

TIME

NOTES

[redacted]

Model:	GVI	6002 Flight 111	Card:	5

Performance: Field: Takeoff
Rotation Rate Development AEO

SET UP		NOTES		NOTES
FLAPS:	20	CG	FWD LIM	PITCH RATE NOTED
GEAR:	EXT	L PWR	MTO	
ALT:	FIELD	R PWR	MTO	
A/S:	NOTED	Bleed	ECS	
Weight	HEAVY	PITCH	NOTED	

RUN	TEST DESCRIPTION

25.101, 25.105, 25.107

1. Configure aircraft for takeoff with/except: as specified

2. Align aircraft on runway and apply brakes

3. Set L & R PWR: as specified; release brakes

4. Rotate at VR at target rotation rate to _____ pitch attitude.

5. Maintain target pitch attitude until V2+10 is achieved.

6. Retract gear after positive rate-of-climb (ROC) is established.

7. Adjust pitch attitude to maintain V2+10 to gear retraction or 400 ft AGL.

A 93-321.3 HIGH RISK STICK FRC:____ , VR + __

<> Repeat as necessary.

TIME	NOTES

Model:	GVI	6002 Flight 111	Card:	6
		Initial Taxi		

TIME

NOTES

[redacted]

Model:	GVI	6002 Flight 111	Card:	7
Brake Sys Development / Performance: Field: Landing				

[redacted]

TIME

NOTES

Model:	GVI	6002 Flight 111	Card:	8

Brake Sys Development / Performance: Field: Accelerate-Stop

[redacted]

TIME

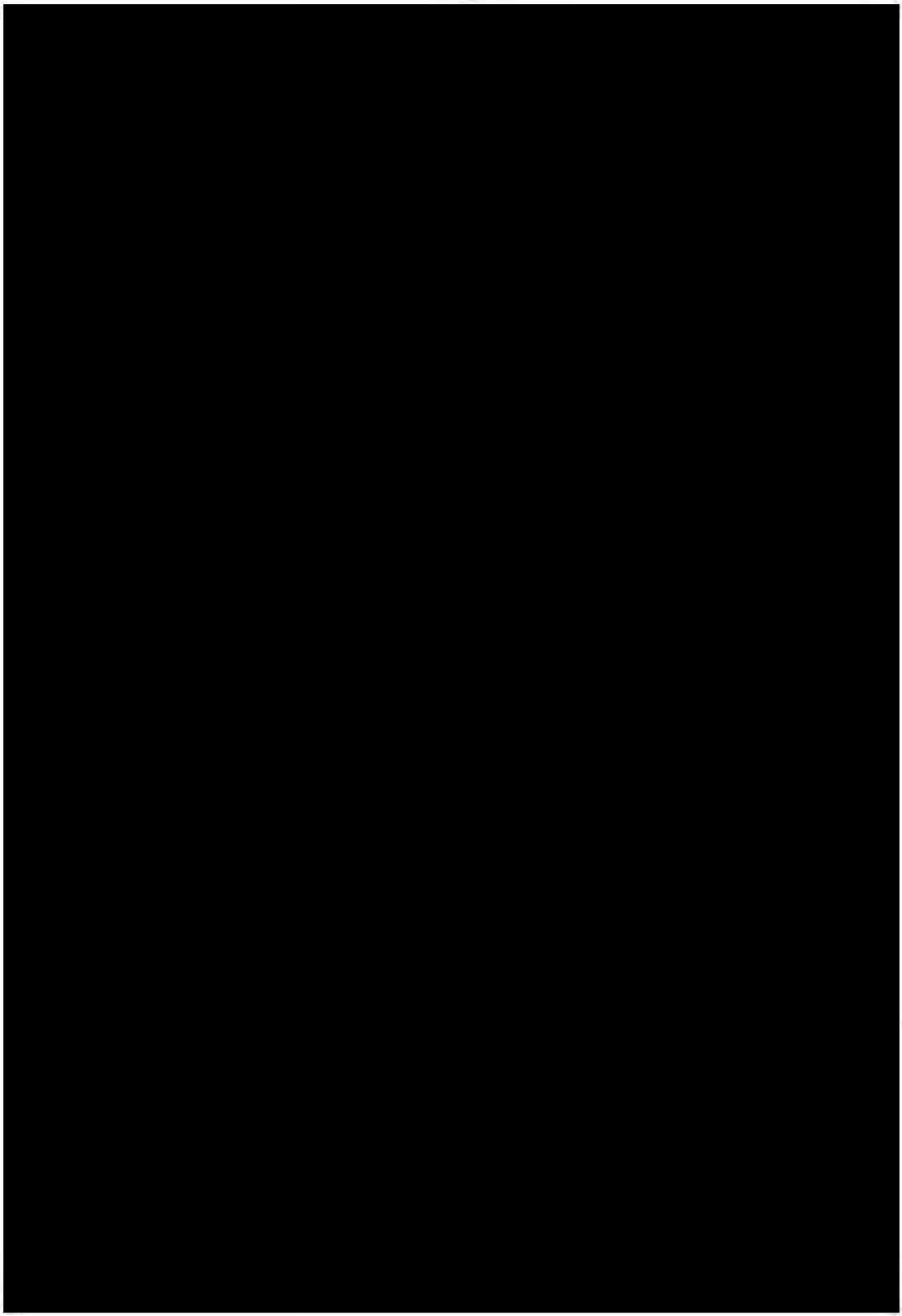
NOTES

[redacted]

G650 Flaps-20 Reference Speeds (Sea-level, std day)				
Weight	V1	Vr	V2	Vsr
100,000	133.3	135.6	141.8	125.4
95,000	128.2	131.8	137.9	122.1
90,000	123.0	128.0	134.0	118.6
85,000	117.5	124.1	130.0	115.0
80,000	114.7	120.1	125.9	111.4
75,000	115.0	116.0	121.8	107.8
70,000	115.3	115.3	121.0	104.1
65,000	115.7	115.7	121.3	100.3
60,000	116.1	116.1	121.7	96.3
55,000	116.6	116.6	122.1	92.2

[redacted]

G650 Flaps-20 Reference Speeds Sea Level Field Elevation, Standard Day						
Weight (lbs)	BFL	V1	Vr	Vlo OEI	V2	Vsr
100000	5896	133.4	135.6	140.1	141.8	125.4
99000	5769	132.4	134.8	139.3	141.0	124.8
98000	5644	131.3	134.1	138.6	140.2	124.1
97000	5522	130.2	133.3	137.8	139.5	123.4
96000	5402	129.2	132.6	137.1	138.7	122.7
95000	5284	128.1	131.8	136.3	137.9	122.1
94000	5168	127.1	131.1	135.5	137.1	121.4
93000	5054	126.0	130.3	134.8	136.4	120.7
92000	4942	124.9	129.5	134.0	135.6	120.0
91000	4835	123.9	128.8	133.2	134.8	119.3
90000	4726	122.8	128.0	132.5	134.0	118.6
89000	4618	121.8	127.2	131.7	133.2	117.9
88000	4512	120.7	126.4	130.9	132.4	117.2
87000	4408	119.6	125.6	130.1	131.6	116.5
86000	4306	118.5	124.9	129.3	130.8	115.8
85000	4206	117.4	124.1	128.5	130.0	115.0
84000	4108	116.2	123.3	127.7	129.2	114.3
83000	4011	115.1	122.5	126.9	128.4	113.6
82000	3915	114.0	121.7	126.1	127.6	112.9
81000	3822	112.9	120.9	125.3	126.7	112.2
80000	3730	111.8	120.1	124.5	125.9	111.4
79000	3639	110.6	119.3	123.7	125.1	110.7
78000	3550	109.5	118.5	122.9	124.3	110.0
77000	3462	108.4	117.7	122.1	123.5	109.3
76000	3377	107.3	116.8	121.3	122.6	108.5
75000	3361	107.4	116.0	120.5	121.8	107.8
74000	3345	107.4	115.2	119.6	121.0	107.0
73000	3329	107.5	114.4	118.8	120.1	106.3
72000	3314	107.6	113.6	118.0	119.3	105.6
71000	3298	107.6	112.7	117.2	118.4	104.8
70000	3283	107.7	111.9	116.3	117.6	104.1
69000	3268	107.8	111.1	115.5	116.7	103.3
68000	3253	107.8	110.2	114.6	115.9	102.5
67000	3238	107.9	109.4	113.8	115.0	101.8
66000	3223	108.0	108.5	112.9	114.1	101.0
65000	3208	108.1	108.1	112.5	113.7	100.3
64000	3193	108.2	108.2	112.6	113.8	99.5
63000	3179	108.3	108.3	112.7	113.9	98.7
62000	3165	108.3	108.4	112.8	113.9	97.9
61000	3151	108.4	108.4	112.9	114.0	97.1
60000	3137	108.5	108.5	113.0	114.1	96.3



ID:	TSHA-000084	Field Performance - Engine-out Takeoffs (OEI)	
Risk:	High	**Probability:**	Low

Test Applicability:

93 - 321	Performance: Field: Takeoff: Rotation Rate Development
93 - 322	Performance: Field: Takeoff: Pitch Attitude Development
93 - 324	Performance: Field: Takeoff: OEI
93 - 325	Performance: Field: Takeoff: Company Development

Hazard: Aircraft Departs Runway/Inadvertent Ground Contact

Cause: Engine Failure/Loss of Control

Effect: Loss of aircraft/loss of crew.

Preventative Actions / Minimizing Procedures:

1. All testing shall be conducted under day VMC conditions on a smooth, hard-surfaced dry runway. ~~Tests shall be conducted at KROW, on Runway 3/21 which is 13000'x300' or KVQQ on Runway 18L/36R which is 12503'x197'.~~
2. Brief local fire and rescue crews on test conditions.
3. Service struts, brakes and tires to recommended limits.
4. Brief dual engine-out emergency procedures.
5. Only crewmembers deemed essential for conduct of the test shall be onboard.
6. Winds will be limited to 10 knots total and components of 5 knots cross wind and 2 knots tail wind.
7. Alternate control law maximum gains will be loaded prior to testing.
8. Testing with fuel cuts will be preceded by testing using a throttle chop to idle power. No engine shutdowns will be conducted without conducting a build-up test. The number of required build-ups and repeat testing will be determined by the on-site test team. Additionally, the pilot flying shall have recent experience with the test maneuver or perform a build-up maneuver(s) before conducting the test condition.
9. Cool brakes as required between test points. Periodically visually inspect brakes and tires and check tire temperatures to maintain below 150 degF.

Corrective Techniques:

1. For throttle chops: if the aircraft is airborne and one engine fails, advance PLA as required, decrease pitch attitude, establish a stable bank angle, accelerate and climb to any altitude. Minimize asymmetric thrust if possible.
2. For fuel cuts: if the aircraft is airborne and operative engine fails, restart shutdown engine, if possible, or conduct dual engine-out landing procedures.
3. Make all turns into the operating engine and climb at no less than V2 until 1500 ft AGL.

Cog Engineer: [redacted] **Test Conductor/Coordinator:** [redacted]

Pilot: [redacted] **Manager:** [redacted]

Gulfstream

TEST SAFETY HAZARD ANALYSIS (TSHA)

TEST: Heavy Braking During Landings, RTOs and High Speed Taxi

RISK LEVEL: HIGH

HAZARD: Departure from Runway. Obstacle Clearance.

CAUSE: Unexpected performance, failure of unproven brake system or NWS issue

EFFECT: Major aircraft damage / Severe personnel injury
Loss of aircraft/crew

PREVENTIVE ACTIONS / MINIMIZING PROCEDURES:

1. Tests conducted in a build-up fashion, from low-speed, moderate braking to higher speed aggressive braking.
2. High-speed braking tests (above 80kts) shall be conducted with a crosswind component not greater than 10 kts (including gusts).
3. High-speed braking tests (above 80kts) shall be conducted on a runway length of at least 8,000 ft and a width of at least 150 ft.
4. Test points shall be conducted under day, VMC conditions on a dry runway, except for the contaminated/wet runway tests.
5. Only crew members deemed essential for the conduct of the test shall be on board (anticipate possible requirement for emergency egress).
6. Flight crew will be equipped with appropriate safety equipment, including flight suits, gloves and boots.
7. Airfield operations and Emergency response crew personnel shall be briefed on planned testing as well as emergency exit locations and procedures.
8. Acceleration during accel-stop tests shall be commensurate with directional control of the aircraft.
9. Tire temperatures will be monitored periodically during taxi runs to maintain tire temps below 150°F.
10. Total brake energy to be managed such that peak BTMS will be maintained below 600°C.

OTHER:

1. **Corrective Technique:** In the event of abnormal braking performance, thrust reversers and/or Parking brake may be used to control the speed of the aircraft.
2. Testing will be discontinued if tires show excessive wear as evidenced by severe flat spotting or more than 4 cords shown on tires.

COG ENGR [redacted] **TEST CONDUCTOR/COORDINATOR:** [redacted]

PILOT: [redacted] **MANAGER, FTE** [redacted]

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FLIGHT TEST CARDS

Reg. No. N652GD [redacted] Serial No: 6002 Flight No: 132 Date: 3/14/11

RO FUEL WEIGHT	[redacted]	TAKEOFF GROSS WEIGHT	[redacted]	FLAPS 20	FLEX [Rated] RATED
ZERO FUEL C.G.		TAKEOFF C.G.		V1 / VR 110/112	VSE 158
FUEL LOAD – LEFT		TOTAL FUEL		V2 116	VREF [redacted]
– RIGHT				FIELD 3862	TO TRIM

VHF TEST FREQUENCIES **SATCOM Number**

[redacted]

AIRCRAFT CONFIGURATION / TEST SUPPORT

[redacted]

LIMITATIONS / RESTRICTIONS

[redacted]

3. HUD combiner misaligned in pitch – use caution on landing
4. Use pre-activation stall speed schedule for F0 Vref calculations per FS-AERO-10-033 RevA (GVI Stall Speeds Rev A.xls)
5. FCS Normal Mode OK, Max Alt gains should be loaded for TO/landing

[redacted]

HAZARDS/TSHA's

1. Performance Braking – Normal and Abnormal (MED)
2. Takeoff Performance (HIGH)
3. RTO (MED)

EMERGENCY EQUIPMENT

3. Fire Extinguishers (3) & Fire Axe
4. First Aid Kit
5. Life raft
6. O2 Walkaround Bottles

DATA SYSTEMS

[redacted]

6002 Call in: [redacted]

PURPOSE OF TEST: **COMPANY**

1. Takeoff Performance
2. Performance Braking
3. RTO's

CREW:

1. Gary Fremman
2. Vivan Ragusa
3. Reece Ollenburg
4. Valerie Thurston ←

ENG START	1308 / 1307	Go Around's	
ENG SHUT DOWN	/	Full Stop	12
CHOCKS IN	1806	Touch & Go's	
TAXI	1314	Total Landings	12
BLOCK TIME	4.52	LANDING	1800
		TAKEOFF	1324
		TOTAL FLIGHT	4+36

Aircraft Configuration Release	FTE Configuration Acceptance

[redacted] Recording Factual Report

GVI Level Flight Weight/CG Envelope

GULFSTREAM AEROSPACE CORPORATION
AIRCRAFT WEIGHT AND BALANCE CALCULATION

DATE	14-Mar-11
MODEL:	GVI
SERIAL NO:	SN6002
REGISTRATION:	N652GD
FLIGHT:	132

	WEIGHT	ARM	MOMENT	% MAC
Form C Weight		[redacted]		[redacted]
Pilot				
Co-Pilot				
Jumpseat				
FTI/STI workstation				
L FTE workstation				
R FTE Workstation				
EMS Workstation				
AV Workstation				
Entryway Ballast				
L ferry crew seat				
L ferry crew seat				
L ferry crew seat				
Baggage Allowance				

	WEIGHT	ARM	MOMENT	% MAC
ZERO FUEL GROSS WEIGHT		[redacted]		[redacted]
TOTAL FUEL LOAD				[redacted]
RAMP GROSS WEIGHT				
START AND TAXI FUEL				
TAKEOFF FUEL LOAD				
TAKE-OFF GROSS WEIGHT				[redacted]

PREPARED BY:
3/13/2011
Wilfert

TAKEOFF C.G. LIMITS	% MAC
FWD CG LIM =	[redacted]
AFT CG LIM =	

COMMENTS
Brakes Company Testing
2 FTEs Takeoff Performance

GVI Level Flight Weight/CG Envelope

MODEL: GVI

SERIAL NO: SN6002

REGISTRATION: N652GD

FLIGHT: 132

[redacted]

Aircraft Weight (lbs)

[redacted]

Model:	Gvl	6002 Flight ~~130~~ 132	Card:	3

Performance: Field: Takeoff

OEI

SET UP		NOTES		NOTES	
FLAPS:	20	CG	FWD LIM	FCC:	FIRST FLT
GEAR:	EXT	L PWR	NOTED	SHAKER:	90% NAOA
ALT:	FIELD	R PWR	NOTED	AOA LMTR:	+0.16 deg
A/S:	0	Bleed	ECS		
Weight	~~MEDIUM~~ LIGHT				

RUN	TEST DESCRIPTION

25.101, 25.105, 25.107, 25.113, 25.101, 25.105, 25.107, 25.113

1. Configure aircraft for takeoff with/except: as specified
2. Align aircraft on runway and apply brakes
3. Set L & R PWR: as specified
4. Release brakes
5. At target Vef (V1 – 20) , fail RH engine using a throttle chop to IDLE.
a. Use rudder and NWS control as required for directional control
6. Rotate at Vr using 70 lb pull until rotation begins, reduce force to gradually capture 9° pitch attitude.
7. Maintain target pitch attitude until V2 is achieved, then transition to speed.
8. Retract gear after positive Rate-Of-Climb ROC is established.
9. Adjust pitch attitude to maintain V2 to the lesser of gear retraction complete or 400 ft AGL.

Do last

Do 1st

- A 93-324.5 HIGH RISK L PWR:MTO
  R PWR: MTO to throttle chop to IDLE
- B 93-324.6 HIGH RISK L PWR: Med Gradient
  R PWR: Med Gradent to throttle chop to IDLE
- C 93-324.7 HIGH RISK L PWR: Low Gradient
  R PWR: Low Gradent to throttle chop to IDLE

<>

[redacted]

TIME	NOTES
	[redacted]

ID:	TSHA-000084	Field Performance - Engine-out Takeoffs (OEI)	
Risk:	High	**Probability:**	Low

Test Applicability:

93 - 321	Performance: Field: Takeoff: Rotation Rate Development
93 - 322	Performance: Field: Takeoff: Pitch Attitude Development
93 - 324	Performance: Field: Takeoff: OEI
93 - 325	Performance: Field: Takeoff: Company Development

Hazard: Aircraft Departs Runway/Inadvertent Ground Contact

Cause: Engine Failure/Loss of Control

Effect: Loss of aircraft/loss of crew.

Preventative Actions / Minimizing Procedures:

1. All testing shall be conducted under day VMC conditions on a smooth, hard-surfaced dry runway. Fuel cut tests shall be conducted at KROW, on Runway 3/21 which is 13000'x300'. Non-fuel cut tests shall be conducted on a runway of at least 12000' in length and at least 150' in width.
2. Brief local fire and rescue crews on test conditions.
3. Service struts, brakes and tires to recommended limits.
4. Brief dual engine-out emergency procedures.
5. Only crewmembers deemed essential for conduct of the test shall be onboard.
6. Winds will be limited to 10 knots total and components of 5 knots cross wind and 2 knots tail wind.
7. Alternate control law maximum gains will be loaded prior to testing.
8. Testing with fuel cuts will be preceded by testing using a throttle chop to idle power. No engine shutdowns will be conducted without conducting a build-up test. The number of required build-ups and repeat testing will be determined by the on-site test team. Additionally, the pilot flying shall have recent experience with the test maneuver or perform a build-up maneuver(s) before conducting the test condition.
9. Cool brakes as required between test points. Periodically visually inspect brakes and tires and check tire temperatures to maintain below 150 degF.

Corrective Techniques:

1. For throttle chops: if the aircraft is airborne and one engine fails, advance PLA as required, decrease pitch attitude, establish a stable bank angle, accelerate and climb to any altitude. Minimize asymmetric thrust if possible.
2. For fuel cuts: if the aircraft is airborne and operative engine fails, restart shutdown engine, if possible, or conduct dual engine-out landing procedures.
3. Make all turns into the operating engine and climb at no less than V2 until 1500 ft AGL.

Cog Engineer:	[redacted]	**Test Conductor/Coordinator:**	[redacted]
Pilot:	[redacted]	**Manager:**	[redacted]

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INTEROFFICE MEMO

From:	Shelly Brimmeier	672/Performance	[redacted]	[redacted]	5/10/2011
	Name	Group	M/S	Ext.	Date

To: Tom Ramee

cc: Tim Farley, Tom Lavrisa, Barry McCarthy

Subject: Notes from Roswell Continued Takeoff Technique Discussion, and from ACSN 6002 Flight 153 Pre-Flight Brief

Enclosures:

1. Shelly Brimmeier's Handwritten Notes from CTO Technique Brief ..... (1 page)
2. Shelly Brimmeier's Flight 153 Test Cards .....(14 pages)

DISCUSSION

My name is Shelly Brimmeier. I am a Group Head for the Aircraft Performance Group, Department 672. I am also an FAA appointed Flight Analyst Designated Engineering Representative (DER). For the past five years, I have been the G650 Aircraft Performance Focal, and dealt with all aircraft performance related inquiries for the G650 program. This includes analysis for all phases of flight, including takeoff, climb, cruise, descent, approach and landing. I have been intimately involved in the planning efforts for field performance testing, including review of the GVI Airplane Performance Certification Plan (GVI-GER-1690, Rev C) and an informal review of the GVI Field Performance Certification Flight Test Plan (GVI-FT-082, Rev A). I was involved in discussions regarding acceptable test requirements that were ultimately defined in GVI-FT-082, Rev A. I was on-site in Roswell to support field performance development testing in November 2010, and to support further field performance development and company testing in March and April 2011. Field performance testing includes Continued Takeoff (CTO), Rejected Takeoff (RTO), Landing in all flap configurations, Minimum Unstick Speed (VMU) determination, as well as other required certification test points. My role was to monitor the testing from the telemetry trailer. I was able to provide real-time analysis of the data moments after it was collected, in addition to the data review that was being performed by the onboard flight test engineers (FTE's), and telemetry trailer test conductor. In the case of CTO, I was primarily watching the target parameters in the following list, and performing an initial examination of the case to determine if it met the test success criteria outlined in GVI-FT-082, Rev A, or as discussed with the flight crew prior to the flight.

- takeoff decision speed (V1)
- rotation speed (VR)
- takeoff safety speed (V2) for single engine, or speed at 35 feet (V35) for twin engine operations
- pitch rate
- pitch at liftoff
- peak pitch throughout the takeoff
- column pull force

I was on-site in Roswell from March 4 – 16, 2011 then returned March 25 – April 2, 2011. During this time, I was the technical lead for the members of the performance group that were in attendance. There were three performance engineers in Roswell during testing, and the team was on a rotational schedule to expose many members of the group to the experience of witnessing flight testing.

As the technical lead for the performance group, I attended all flight briefs that related to field performance, and was involved in the test planning including test procedures. I was able to discuss intent of the test with the crew, but the crew ultimately decided upon the appropriate procedures they would employ.

I attended two meetings that were held on Friday, April 1, 2011 to prepare for ACSN 6002 Flight 153. The first was the CTO Technique Brief held at approximately 2:00 PM. The CTO Technique meeting was attended by the crew (Kent Crenshaw, Vivan Ragusa, Reece Ollenburg and David McCollum), as well as FTE Cynthia Townsend, and myself. During much of the Roswell testing, Cynthia's role was Telemetry Test Conductor. The purpose of this meeting was to discuss the single engine continued takeoff technique that had been previously tested in Roswell in November 2010, in Birmingham in February, and again in Roswell in early March 2011. Reece had performed data reduction on the test data and discussed results with Pat Connor (Aircraft Performance Principal Engineer and Flight Analyst DER). Their discussions led to the proposed technique discussed, as well as Integrated Test Facility (ITF) testing of sample cases performed by Vivan and Reece prior to their arrival in Roswell that day. Notes from this meeting are attached as Enclosure 1.

The following paragraphs recount my recollection of the discussion held during the CTO Technique Brief.

> The purpose of Flight 153 was to perform heavyweight continued takeoffs, and as time permitted to proceed to medium weight CTOs. The takeoff testing was intended to be to practice the small revisions that were made to the takeoff technique to ensure that it was repeatable. It was discussed that each takeoff condition would be completed two or three times to collect a good set of data to compare to previous testing. The takeoff pitch angle to target was 9 degrees for flaps 20 or flaps 10 takeoffs, realizing that there is a tolerance of +/- 1 degree. This target was agreed upon by Reece, Pat and Ken Obenshain (Staff Scientist FTE, Flight Analyst DER), and myself. Further discussion of this target included Reece and Kent reflecting on a previous pitch overshoot during VMU testing, saying comments like "we've already been there, we don't want to go there again" and indicating that if they saw 11 or 12 degrees, it was a knock-it-off and recover maneuver. Kent was particularly concerned about the pitch overshoot, saying that he "didn't like it."
>
> The next discussion point was how to fly the maneuver. This was primarily the pilots discussing what reference system to use to watch the pitch angle in the cockpit. It was discussed that Jake Howard (Experimental Test Pilot, Lead G650 Pilot, Pilot DER) uses the cross-pointer on the flight director to target pitch on previous flights, that a pilot could use the HUD for flight path only and the scale on synthetic vision is too small, but may work better for speed. It was determined that the cross-pointer on the primary flight display (PFD) was the method to employ. Once we decided how to capture pitch, the discussion moved to discuss the maneuver from liftoff to 35 feet. The intent was for the pilots to capture the pitch of 9 degrees, but not fixate on holding 9 degrees for a period of time. The crew discussed capturing pitch for liftoff, then transitioning to targeting the V2 speed by the time the aircraft reached 35 feet Above Airport Level (AAL).

Next the discussion moved to pull force and how to apply pressure to the column. We discussed a slightly slower pull (rather than the ramp input that had been employed previously) to a force of about 60-65 pounds. A comment from Kent about the 60 pound target pull force was that it would be more repeatable, and would not be dependent upon jerking the airplane controls around. An objective of slowing the pull technique was to reduce the amount of "bobble" on pitch. This means that the pitch was peaking out, decreasing quite a bit, and then recovering throughout the climb. By slowing the pull technique we hoped to reduce the push that followed liftoff, which consequently reduced the nose attitude, adding time to the liftoff to V2 portion of the takeoff. Reece proposed targeting a 6 degree per second pitch rate, and all agreed that sounded reasonable. We also discussed that the target time from rotation to liftoff was 3-4 seconds for a max takeoff weight condition.

Other pilot discussion revolved around the pitch limiter coming up on the screen while flying these CTOs. It was discussed that the limiter was set to an arbitrary limit, and should be pushed out of the way for production G650 aircraft so that the customer pilots would not see that during a takeoff if repeating this technique. The pilots also discussed the Normalized Angle of Attack (NAOA) set-up on the legacy aircraft.

The meeting concluded with discussion of the key parameters to watch during the CTO testing. They are included in the list below.

- Technique
- Speed Variation
- Stick Force
- Pitch Rate

We also discussed that if the winds became out of limits for CTOs that the testing of Rejected Takeoff (RTO) test points would continue.

The second meeting on Friday, April 1, 2011 was the Pre-Flight Brief to review current aircraft configuration, flight cards, test procedures, applicable Test Safety Hazard Analysis (TSHA). This meeting was held at approximately 6:00 PM, and was attended by the crew, Cynthia Townsend, Eric Upton (aircraft performance engineer) and myself. The meeting began with review of the Flight 153 Test Cards. Each page of the test cards was briefed. Reece basically ran the meeting, detailing the aircraft configuration, limitations/restrictions, test procedures for each card, and following up with TSHA review. I did not take notes at this meeting, but the following paragraphs detail discussions that I recall.

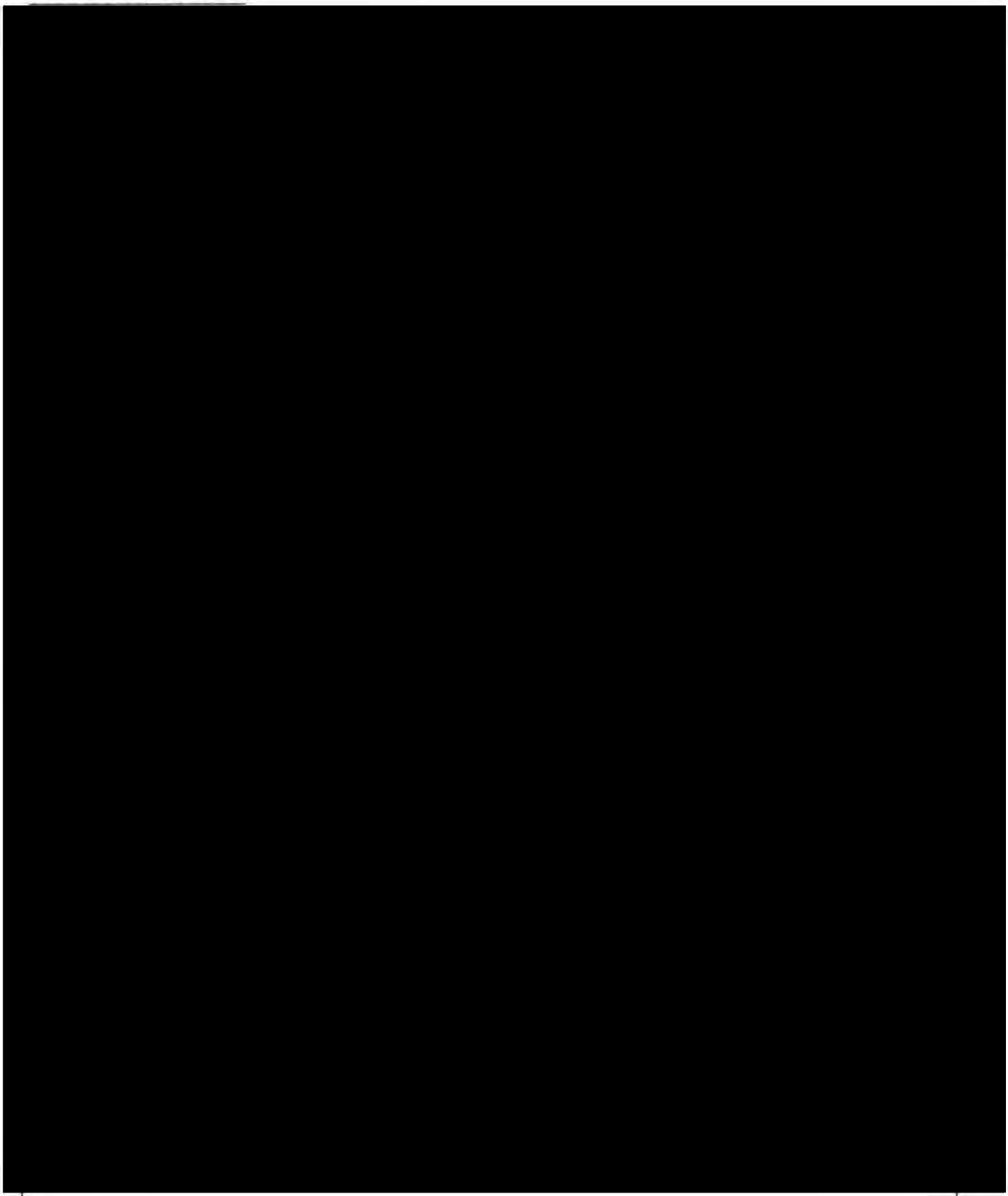
Each CTO configuration (both flaps 10 and 20) were to be performed targeting a 9 degree pitch attitude, and whether twin engine (All engines Operating – AEO) or single engine (One Engine Inoperative – OEI), use a 60-65 pound pull force. The previous pitch targets were printed on the cards, but each individual marked up their cards to reflect the 9 degree target for both flaps 10 and 20. Also printed on the cards were procedures for low or medium gradients. These were not performed. All takeoffs were performed at max takeoff thrust settings. It was agreed that each CTO card would be performed about three times. Also printed on the cards was a procedure to simulate hydraulic failure. During previous Roswell testing, Reece determined that there was negligible effect on takeoff distance or controllability, so the crew agreed that it was safer to not fail the right hydraulics. This procedure was crossed out on the CTO OEI cards. Kent and Vivan agreed that a takeoff would be called a knock-it-off, and pitch would be corrected by column push if they were to see 11 or 12 degrees. Kent again said, "I don't want to go there." Once each takeoff procedure card was briefed, the team moved on to brief the TSHA's. Each entire TSHA was discussed, including the corrective techniques.

The pilots' discussion about "not wanting to go there" and "I didn't like it" at the high pitch attitudes can be traced back to previous tests. Each pilot had experienced a pitch overshoot on AC SN 6002 flights with Reece on board as primary FTE. I was on-site in Roswell for each of these flights, and attended pre-flight briefs and post-test debriefs.

Kent's experience was on Flight 88 in November Roswell testing, where the target pitch was overshot during a VMU test point. At that time, it was determined that a build-up in test conditions was required for the Pilot in command. The previous VMU test points were flown on previous flights by Jake Howard. TSHA was amended to reflect this change. I have a TSHA-000085 Rev A that includes handwritten mark-ups that was updated on 11/16/2010 that Reece and Jake initialed, and we briefed Rev A for Flight 089 and 090. Specifically, the Rev A version adds under Preventative Actions/ Minimizing Procedures: 12. Pilot flying shall perform a buildup test condition/maneuver. After return to Savannah, this was formally added to the TSHA. Kent also made comments about wanting to get the video of this run, intending to use it as a safety teaching point for all of the pilots.

Vivan's pitch overshoot occurred on Flight 132. Again, it was the first time he was performing CTO test points. The first run (3B) he delayed the rotation too late, missing the target VR by 4 knots. On the following run (3B1), he corrected, anticipating the rotation too early. During this maneuver, Gary Freeman was the co-pilot. He corrected with a column push and roll. Discussion immediately after the maneuver was that "at lighter weights the pull needs to be done slower." The comments post-flight were that the aircraft rolled right and yawed right. At the time an IFR was in effect that the yaw damper be disabled in flight. Post-flight discussions between Gary, Vivan and Reece were that the yaw damper was required for this testing, and we would not continue without it being active.

Enclosure 2 includes Aircraft Serial Number (ACSN) 6002 Flight Test Cards for Flight 153 on Saturday, April 2, 2011. These cards include my own handwritten notes pertaining to the CTO test that were being conducted at the time of the accident.



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FLIGHT TEST CARDS

Reg. No. **N652GD** Serial No: **6002** Flight No: **153** Date: **4/2/11**

FUEL WEIGHT	[redacted]	TAKEOFF GROSS WEIGHT	[redacted]	FLAPS	20
ZERO FUEL C.G.		TAKEOFF C.G.		V1 / VR	132/134
FUEL LOAD – LEFT		TOTAL FUEL		V2	138
– RIGHT				FIELD	[redacted]

FLEX [Rated]	RATED		
VSE	[redacted]		
VREF			
TO TRIM			

VHF TEST FREQUENCIES **SATCOM Number**

[redacted]

AIRCRAFT CONFIGURATION / TEST SUPPORT

1. [redacted]
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.
22.
23.

LIMITATIONS / RESTRICTIONS

1. [redacted]
2.
3.
4. Use pre-activation stall speed schedule for F0 Vref calculations per FS-AERO-10-033 RevA (GVI Stall Speeds Rev A.xls)
5. **FCS Normal Mode Restricted, IFR FCS-038A**
6. [redacted]
7.
8.

HAZARDS/TSHA's

1. TSHA-000084 Performance Takeoffs OEI (High)
2. TSHA-000085 Performance Accelerate-Stop (Medium)
3.

EMERGENCY EQUIPMENT

4. Fire Extinguishers (3) & Fire Axe
5. First Aid Kit
6. Life raft
7. O2 Walkaround Bottles

DATA SYSTEMS

[redacted]

6002 Call in: [redacted]

PURPOSE OF TEST: **Development**

1. Performance Takeoff
2. Performance RTO
3.

CREW:

1. Kent Crenshaw
2. ~~Chip King~~ VIVAN KAGUSA
3. Reece Ollenburg
4. Dave McCollum

High Power Shutdowns Remaining	38 / 41	Go Around's	
High Power Shutdowns This Flight	/	Full Stop	
ENG START	/	Touch & Go's	
ENG SHUT DOWN	/	Total Landings	
CHOCKS IN		LANDING	
TAXI		TAKEOFF	
BLOCK TIME		TOTAL FLIGHT	

Aircraft Configuration Release

FTE Configuration Acceptance

GVI Level Flight Weight/CG Envelope

GULFSTREAM AEROSPACE CORPORATION
AIRCRAFT WEIGHT AND BALANCE CALCULATION

DATE	02-Apr-11
MODEL:	GVI
SERIAL NO:	SN6002
REGISTRATION:	N652GD
FLIGHT:	**153**

	WEIGHT	ARM	MOMENT	% MAC
Form C Weight		[redacted]		[redacted]
Pilot				
Co-Pilot				
Jumpseat				
FTI/STI workstation				
L FTE workstation				
R FTE Workstation				
EMS Workstation				
AV Workstation				
Entryway Ballast				
L ferry crew seat				
L ferry crew seat				
L ferry crew seat				
Baggage Allowance				

	WEIGHT	ARM	MOMENT	% MAC
ZERO FUEL GROSS WEIGHT		[redacted]		[redacted]
TOTAL FUEL LOAD				[redacted]
RAMP GROSS WEIGHT				
START AND TAXI FUEL				
TAKEOFF FUEL LOAD				
TAKE-OFF GROSS WEIGHT				[redacted]
				[redacted]

PREPARED BY:
4/1/2011
Wilfert

TAKEOFF C.G. LIMITS	% MAC
FWD CG LIM =	[redacted]
AFT CG LIM =	

COMMENTS
FWD LIM CG

[redacted]

4/1/2011

Aircraft Weight (lbs)

[redacted]

[redacted]

4/1/2011

Model:	GVI	6002 Flight 153	Card:	1
		Initial Power Up		

TIME

Comments

[redacted]

Model:	C	6002 Flight 153	Card:	2

Performance: Field: Takeoff

AEO

SET UP		NOTES		NOTES	
FLAPS:	20	CG	FWD LIM	FCC:	FIRST FLT
GEAR:	EXT	L PWR	NOTED	SHAKER:	
ALT:	FIELD	R PWR	NOTED	AOA LMTR:	
A/S:	0	Bleed	ECS		
Weight	MTOW				

RUN **TEST DESCRIPTION**

25.101, 25.105, 25.107, 25.109, 25.113

1. Configure aircraft for takeoff.

2. Align aircraft on runway and apply brakes

3. Set L &R PWR: as specified

4. Release brakes

5. Rotate at VR using 45 lbs pull until rotation begins, reduce force to gradually capture 9° pitch attitude.

6. Maintain target pitch attitude until Rate-of-Climb V2+10 is achieved, then transition to speed. Do not exceed 20° pitch attitude.

7. Retract gear after positive ROC is established (1 second wait)

8. Adjust pitch attitude to maintain V2+10 to the lesser of gear retraction complete or 400 ft AGL.

~~A 93-323.1~~
~~L & R PWR: Low Gradient~~

@ V2+10 TRIM CHECK

~~B 93-323.2~~
~~L & R PWR: Med Gradient~~

C 93-323.3
L PWR:MTO R PWR:MTO

2C1

<>

[redacted]

Model:	G	6002 Flight 153	Card:	3

Performance: Field: Takeoff

OEI

SET UP		NOTES		NOTES	
FLAPS:	20	CG	FWD LIM	FCC:	FIRST FLT
GEAR:	EXT	L PWR	NOTED	SHAKER:	90% NAOA
ALT:	FIELD	R PWR	NOTED	AOA LMTR:	+0.16 DEG
A/S:	0	Bleed	ECS		
Weight	MTOW				

RUN	TEST DESCRIPTION
	25.101, 25.105, 25.107, 25.113 1. Configure aircraft for takeoff with/except: as specified 2. Align aircraft on runway and apply brakes 3. Set L & R PWR: as specified 4. Release brakes 5. At target Vef (V1 – 20) , fail RH engine using a throttle chop to IDLE. a. Use rudder and NWS control as required for directional control 6. Rotate at Vr using ___ lb pull until rotation begins, reduce force to gradually capture 9° pitch attitude. 7. Maintain target pitch attitude until V2 is achieved, then transition to speed. 8. Retract gear after positive Rate-Of-Climb ROC is established. 9. Adjust pitch attitude to maintain V2 to the lesser of gear retraction complete or 400 ft AGL. [redacted]
A	93-324.9 HIGH RISK L PWR:MTO [redacted] R PWR: MTO to throttle chop
B	93-324.10 HIGH RISK [redacted] L PWR: Med Gradient, R PWR: Med Gradent to throttle chop
<>	

TIME	NOTES
	[redacted]

Model:	GVI	6002 Flight 153	Card:	4	TIME	NOTES

[redacted]

Model:	C	6002 Flight 153	Card:	5	TIME	NOTES

[redacted]

Model:	C	6002 Flight 153	Card:	6

Performance: Field: Takeoff

AEO

SET UP		NOTES		NOTES	
FLAPS:	10	CG	FWD LIM	FCC:	FIRST FLT
GEAR:	EXT	L PWR	NOTED	SHAKER:	90% NAOA
ALT:	FIELD	R PWR	NOTED	AOA LMTR:	+0.16 DEG
A/S:	0	Bleed	ECS		
Weight	MTOW				

RUN	TEST DESCRIPTION

25.101, 25.105, 25.107, 25.109, 25.113

1. Configure aircraft for takeoff.

2. Align aircraft on runway and apply brakes

3. Set L &R PWR: as specified

4. Release brakes

5. Rotate at VR using _____ lbs pull until rotation begins, reduce force to gradually capture ~~10°~~ 9° pitch attitude.

6. Maintain target pitch attitude until Rate-of-Climb V2+10 is achieved, then transition to speed. Do not exceed 20° pitch attitude.

7. Retract gear after positive ROC is established.

8. Adjust pitch attitude to maintain V2+10 to the lesser of gear retraction complete or 400 ft AGL.

[redacted]

~~A 93-323.10~~
~~L & R PWR: Low Gradient~~

~~B 93-323.11~~
~~L & R PWR: Med Gradient~~

C 93-323.12
L PWR:MTO R PWR:MTO

<>

TIME	NOTES
[redacted]	

Model: C	6002 Flight 153	Card: 7

Performance: Field: Takeoff

OEI

SET UP		NOTES		NOTES	
FLAPS:	10	CG	FWD LIM	FCC:	FIRST FLT
GEAR:	EXT	L PWR	NOTED	SHAKER:	90% NAOA
ALT:	FIELD	R PWR	NOTED	AOA LMTR:	+0.16 DEG
A/S:	0	Bleed	ECS		
Weight	MTOW				

RUN **TEST DESCRIPTION**

25.101, 25.105, 25.107, 25.113

1. Configure aircraft for takeoff with/except: as specified
2. Align aircraft on runway and apply brakes
3. Set L & R PWR: as specified
4. Release brakes
5. At target Vef , fail RH engine using a throttle to IDLE.

a. Use rudder and NWS control as required for directional control

6. Rotate at Vr+2 using ____ lb pull until rotation begins, reduce force to gradually capture 10° pitch attitude.
7. Maintain target pitch attitude until V2 is achieved, then transition to speed.
8. Retract gear after positive Rate-Of-Climb ROC is established.
9. Adjust pitch attitude to maintain V2 to the lesser of gear retraction complete or 400 ft AGL.

A 93-324.21 HIGH RISK
L PWR:MTO ~~R HYD DEPRESS:MAN DEPRESS~~
R PWR: MTO to throttle chop

B 93-324.22 HIGH RISK
~~R HYD DEPRESS:MAN DEPRESS~~
L PWR: Med Gradient, R PWR: Med Gradent to throttle chop

<>

TIME			NOTES
7A1	V1	126	Rwy 21
	VR	128	128.0
15:25:50 BR	Trim	8.0	
	V2	136	144.8
	VTC	~~100~~	
	θ LO		4.2 deg
	PK FRC		50.9 lbs
	θrate		5.4
7A2	V1	125	Rwy 21
	VR	127	
15:33:17 BR	V2	135	
	Trim		
	θLO		
	θPK		
	PK FRC		
	θrate		

INCIDENT OCCURRED ON THIS POINT.

Model:	G	6002 Flight 153	Card:	7

Performance: Field: Takeoff

OEI

SET UP		NOTES		NOTES	
FLAPS:	10	CG	FWD LIM	FCC:	FIRST FLT
GEAR:	EXT	L PWR	NOTED	SHAKER:	90% NAOA
ALT:	FIELD	R PWR	NOTED	AOA LMTR:	+0.16 DEG
A/S:	0	Bleed	ECS		
Weight	MTOW				

RUN	TEST DESCRIPTION
	25.101, 25.105, 25.107, 25.113 1. Configure aircraft for takeoff with/except: as specified 2. Align aircraft on runway and apply brakes 3. Set L & R PWR: as specified 4. Release brakes 5. At target Vef , fail RH engine using a throttle to IDLE. a. Use rudder and NWS control as required for directional control 6. Rotate at Vr+2 using ____ lb pull until rotation begins, reduce force to gradually capture 10° pitch attitude. 7. Maintain target pitch attitude until V2 is achieved, then transition to speed. 8. Retract gear after positive Rate-Of-Climb ROC is established. 9. Adjust pitch attitude to maintain V2 to the lesser of gear retraction complete or 400 ft AGL.
A	93-324.21 HIGH RISK L PWR:MTO R PWR: MTO to throttle chop
B	93-324.22 HIGH RISK L PWR: Med Gradient R PWR: Med Gradent to throttle chop
<>	

TIME	NOTES

Model: C	6002 Flight 153	Card: 8

Landing

SET UP		
FLAPS: 39		
GEAR: DN		
ALT: APR		
A/S: VREF		

RUN	TEST DESCRIPTION
A	RETURN KROW
B	Approach – KROW _____ Type: Visual / ILS / GPS Winds: _____ / _____
C	LAND - Flap 39 Deploy Thrust Reverser A/R Brake: As Required
D	TAXI
E	CHOCKS
F	SHUTDOWN<>

TIME

NOTES

ID:	TSHA-000084	Field Performance - Engine-out Takeoffs (OEI)	
Risk:	High	**Probability:**	Low

Test Applicability:	93 - 321	Performance: Field: Takeoff: Rotation Rate Development
	93 - 322	Performance: Field: Takeoff: Pitch Attitude Development
	93 - 324	Performance: Field: Takeoff: OEI
	93 - 325	Performance: Field: Takeoff: Company Development

Hazard: Aircraft Departs Runway/Inadvertent Ground Contact

Cause: Engine Failure/Loss of Control

Effect: Loss of aircraft/loss of crew.

Preventative Actions / Minimizing Procedures:

1. All testing shall be conducted under day VMC conditions on a smooth, hard-surfaced dry runway. Fuel cut tests shall be conducted at KROW, on Runway 3/21 which is 13000'x300'. Non-fuel cut tests shall be conducted on a runway of at least 12000' in length and at least 150' in width.
2. Brief local fire and rescue crews on test conditions.
3. Service struts, brakes and tires to recommended limits.
4. Brief dual engine-out emergency procedures.
5. Only crewmembers deemed essential for conduct of the test shall be onboard.
6. Winds will be limited to 10 knots total and components of 5 knots cross wind and 2 knots tail wind.
7. Alternate control law maximum gains will be loaded prior to testing.
8. Testing with fuel cuts will be preceded by testing using a throttle chop to idle power. No engine shutdowns will be conducted without conducting a build-up test. The number of required build-ups and repeat testing will be determined by the on-site test team. Additionally, the pilot flying shall have recent experience with the test maneuver or perform a build-up maneuver(s) before conducting the test condition.
9. Cool brakes as required between test points. Periodically visually inspect brakes and tires and check tire temperatures to maintain below 150 degF.

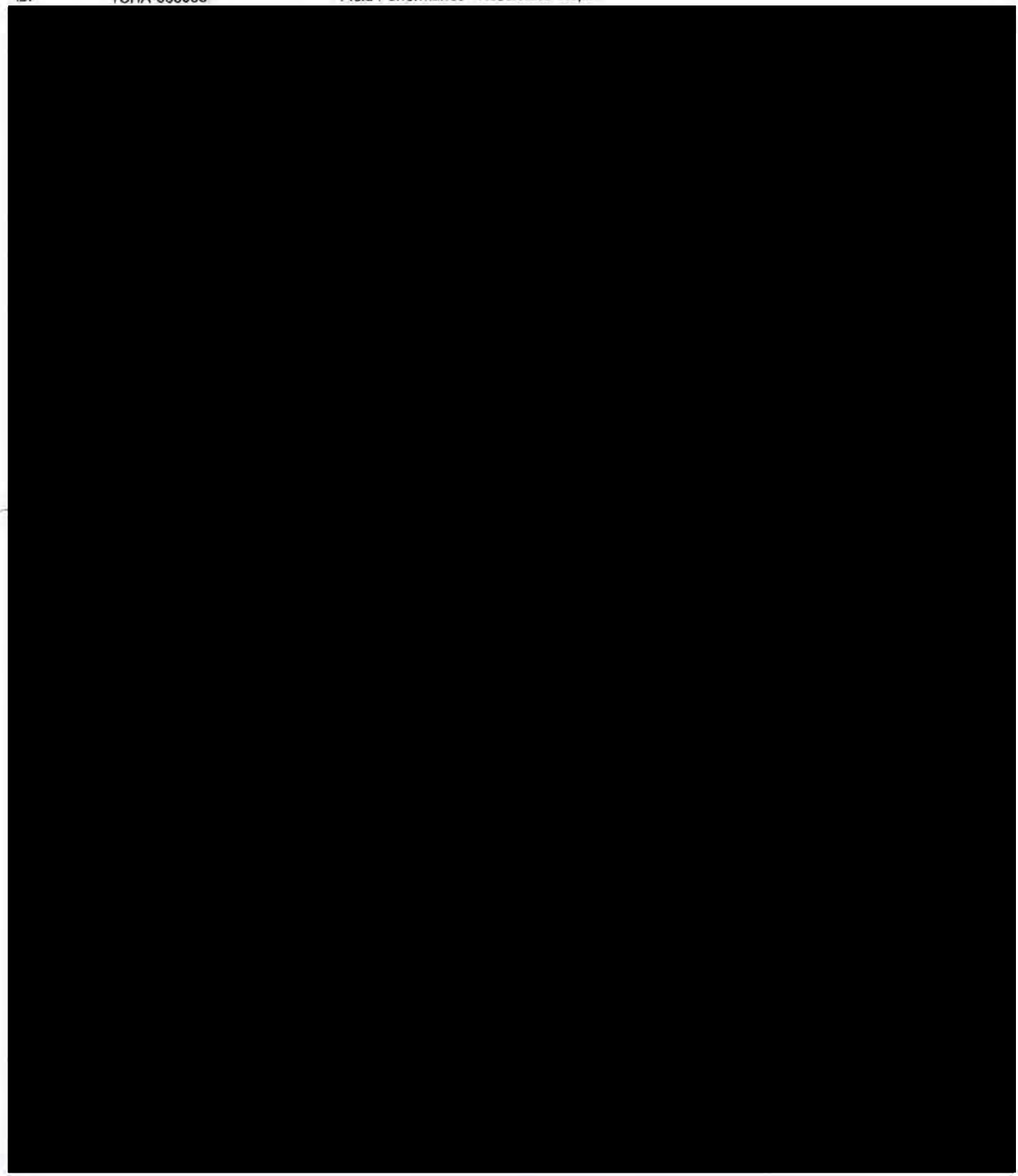
Corrective Techniques:

1. For throttle chops: if the aircraft is airborne and one engine fails, advance PLA as required, decrease pitch attitude, establish a stable bank angle, accelerate and climb to any altitude. Minimize asymmetric thrust if possible.
2. For fuel cuts: if the aircraft is airborne and operative engine fails, restart shutdown engine, if possible, or conduct dual engine-out landing procedures.
3. Make all turns into the operating engine and climb at no less than V2 until 1500 ft AGL.

Cog Engineer: [redacted] **Test Conductor/Coordinator:** [redacted]

Pilot: [redacted] **Manager:** [redacted]

ID: TSHA-000085 Field Performance - Accelerate Stops



Attachment II – Recording Summaries and Transcripts

Summaries and transcripts of on-board video/audio recordings captured by an Epiphan model "VGA Recorder Pro" digital video recorder s/n (unknown), installed on a Gulfstream Aerospace Corporation GVI (G650) experimental airplane, s/n 6002 registration N652GD. The airplane was operated by Gulfstream Aerospace Corporation during a developmental flight test when it crashed on takeoff on April 2, 201,1 at Roswell International Air Center Airport (ROW), Roswell, New Mexico.

These summaries below describe the Group's observations of the recording from the accident test run as well as 50 previous test runs which were flown at various times over the course of field performance testing of the airplane. These summaries occur chronologically.

LEGEND

Flight Crew:

P-1:	Pilot-In-Command (left seat) during the accident flight (all test runs)
P-2:	Second-In-Command (right seat) during the accident flight (all test runs)
P-3:	GAC G650 Project Pilot
P-4	Engineering Test Pilot
FTE-1	Lead Flight Test Engineer for field performance testing during the accident flight (all test runs)
FTE-2	2nd Flight Test Engineer during the accident flight (all test runs)
FTE-3	Flight Test Engineer (Provided support from Savannah, GA on the day of the accident)
FTE-4	Another GAC Flight Test Engineer

Telemetry Trailer Personnel

TM-1	Flight Sciences Airplane Performance Group Head during the accident flight (all test runs)
TM-3	Flight Test Engineering Technical Specialist, Aerodynamics (contracted) during the accident flight (all test runs)
TM-4	Flight Test Engineer Group Head

-?	Voice unidentified
RDO	VHF Radio transmission
#	Expletive
*	(asterisk) unintelligible word or phrase
-	(dash) break or interruption
&	Third party personal name (see note 6 below)

Note1: All of the flight crew and telemetry trailer personnel on duty during the accident flight (except FTE-2) were also involved in one or more of the previous flights documented in this report. For all test runs, the left seat pilot is the Pilot Flying (PF) the maneuver. The left seat pilot is also the Pilot-In-Command (PIC) for all flights except flight 132, during which the right seat pilot was the PIC.

Note2: All times in this report reflect the Greenwich Mean Time (GMT) time zone, which is equivalent to Coordinated Universal Time (UTC), except for those times referenced in the summaries on the day of the accident (04/02/2011). Times on this day reflect the Mountain Daylight Time (MDT) time zone.

Note3: Winds listed for each run are from the best available source (The Gulfstream weather station or telemetry trailer when available, otherwise as provided by the Air Traffic Control Tower).

Note4: Recording start and end times represent the full extent of the recording. Typically the flight crew are not present on the flight deck when the recordings first begin. Little or no audio is available until the crew don their headsets.

Note5: Words in parentheses ( ) are editorial comments. Words in quotation marks “ ” are direct quotations from the attributed speaker, for the summary portions of Attachment II.

Note6: Personal names of 3rd parties not involved in the conversation are generally not transcribed.

Note 7: Words shown with excess vowels, letters, or drawn out syllables are a phonetic representation of the words as spoken.

Other Acronyms and Abbreviations used in this report:

Acronym	Definition
ADI	Attitude Direction Indicator
AEO	All Engines Operating
AGL	Above Ground Level
AOA	Angle of Attack
ATC	Air Traffic Control
CG	Center of Gravity
EPR	Engine Pressure Ratio
EICAS	Engine Indication and Crew Alerting System
FCC	Flight Control Computer
FPA	Flight Path Angle
FWD	Forward
GMT	Greenwich Mean Time (coordinated universal time)
GWS	Gulfstream Weather station
HUD	Heads Up Display
IADS	Flight test engineer's display software
KCAS	Knots Calibrated Airspeed
LIM	Limit
MDT	Mountain Daylight Time
MTO	Maximum Takeoff engine power
MTOW	Maximum Takeoff Weight
NAOA	Normalized Angle of Attack
OAT	Outside Air Temperature
OEI	One Engine Inoperative
PLI	Pitch Limit Indicator
PFD	Primary Flight Display
PWR	Power (engine)
RAAS	Runway Awareness and Advisory System
RTO	Rejected Takeoff
SMC	Standby Multifunction Controller
SV	Synthetic Vision
T/W	Thrust over Weight ratio
TM	Telemetry (or Telemetry trailer)
TSHA	Test Safety Hazard Assessment
V_1	Takeoff Decision Speed
V_2	Takeoff Safety Speed
V_{EF}	Critical Engine Failure Speed
VID	Observation or comment about video portion of recording
V_{LOF}	Liftoff Speed
V_{MC}	Minimum Control Speed
V_{MU}	Minimum Unstick Speed
V_R	Rotation Speed
V_{REF}	Landing Reference Speed
WOW	Weight on Wheels

FLIGHT 081 - V_{MU} Development (HEAVY), Roswell NM November 10, 2010

Notes:
Recording started at about 1300 GMT and ends at 1555 GMT.
The video portion of the recording is intermittent; the audio and time code appear to be normal.
Runway 3 was used for all takeoffs unless otherwise specified.

Crew for this Flight:
P-3 was the Pilot In Command in the left hand seat.
P-1 was in Second In Command the right hand seat.
FTE-1 was the lead Flight Test Engineer.
FTE-4 was the 2nd Flight Test Engineer.
TM-1, **TM-4** were in the telemetry trailer.

Test Cards
The Video Group documented the segments of this flight which related to the following Test Cards:

Card 1: Performance: Field: V_{MU} Development
(selected excerpts from the Test Description section)

- Flaps 20
- Weight: HEAVY
- CG: FWD LIM
- Set L&R PWR:MTO; release brakes.
- During the Initial ground acceleration and prior to 60 KCAS, set L&R PWR: target EPR for test T/W.
- At approximately 60 KCAS apply full aft control column. When aircraft begins to rotate, use control column to capture the target pitch attitude for the test condition and maintain through liftoff until out of ground effect or 100 AGL.

Card 2: Performance: Field: V_{MU} Development
(selected excerpts from the Test Description section)

- Flaps 10
- Weight: HEAVY
- CG: FWD LIM
- Set L&R PWR:MTO; release brakes.
- During the Initial ground acceleration and prior to 60 KCAS, set L&R PWR: target EPR for test T/W.
- At approximately 60 KCAS apply full aft control column. When aircraft begins to rotate, use control column to capture the target pitch attitude for the test condition and maintain through liftoff until out of ground effect or 100 AGL.

Summary of Video/Audio Recording

Prior to the first takeoff, FTE-1 said that $\mathbf{V_{REF}}$ would be based on a 2 degree margin (below the stall reference AOA) and the new $\mathbf{V_2}$ would be based on the latest table provided by TM-1. P-3 said that the stick shaker was set to activate at an angle of attack (AOA) of 11.7 degrees. The flight crew agreed that 10.5 degrees AOA was the "knock it off" AOA. P-3 said, "we should be good all the way to the shaker, but we'll be cautious there." He stated that if an engine failure occurred prior to $\mathbf{V_1}$ they would abort the takeoff. If it occurred after $\mathbf{V_1}$, they would increase thrust on the other engine and carefully maintain directional control. He acknowledged that the Test Safety Hazard Analysis (TSHA) specified that if something happened to the operating engine after liftoff, they would decrease pitch enough so that they would not stall and they would bring both throttles up and use them throughout the climb.

(Card 1A L&R PWR: two eng min T/W plus, target pitch 7-8 degrees)
[1337 GMT]

Winds: 306 at 1
Selected V2: 143 knots
Selected VREF: (unintelligible)
Weight: 100,000 pounds
Selected EPR: 1.30

A margin of 30% was added to the minimum thrust over weight ratio (T/W) to determine the power setting for this run. The crew decided to target 7.5 degrees pitch attitude. During the takeoff, P-3 said he was pulling the control column "full aft." P-1 called out pitch and AOA values during the maneuver.
After the maneuver, the crew noted that the airplane lifted off at 7.5 degrees AOA. P-3 noted that the stick shaker "nibbled" at 146 knots and he kept a "slow pull" on the control column until 13 to 14 degrees of pitch. P-3 observed that there was a slight "bobble" of the pitch during rotation. FTE-1 stated that he had been monitoring the AOA during the maneuver.

(Card 1B L&R PWR: two eng min, target pitch 7-8 degrees)
[1348 GMT]

Winds: 255 at 2.2
Selected $\mathbf{V_2}$: 143 knots
Selected $\mathbf{V_{REF}}$: 156 knots
Weight: 100,000 pounds
Selected EPR: 1.21

FTE-1 instructed the pilots to use an Engine Pressure Ration (EPR) setting of 1.21 for no additional margin on the T/W ratio. He asked the TM trailer to confirm the setting and TM-4 confirmed the setting of 1.21. The crew decided to reduce the thrust at 80 knots instead of 60 knots. P-1 asked what the thrust setting margin was for this run, indicating that the last run was a 30% margin. FTE-1 replied that it was zero for this run, and P-1 acknowledged. P-3 indicated the

pitch target would be 7.5 degrees. After liftoff, P-3 indicated that he was capturing the $\mathbf{V_2}$ of 143 knots. Shortly thereafter, he reported wires approaching and the pilots increased thrust while below 100 feet AGL to climb out. While circling around, the pilots commented that the climb gradient had been very shallow during the takeoff. FTE-1 reported that AOA at liftoff was 7.6 degrees and then increased to 9.5 degrees. The crew discussed whether the power setting had been appropriate. FTE-1 said that the EPR setting was 1.24 and the thrust drooped to 1.196 at liftoff. P-1 said he did not know what FTE-1 was looking at, because the pilots had it set to 1.21.

P-3 commented that they could not use a climb gradient that was any shallower. He also observed that while attempting to capture $\mathbf{V_2}$ at 9 degrees of pitch, the airplane had begun to decelerate. He said he recalled that the minimum EPR setting briefed the night before was 1.18. FTE-1 then observed that two-engine EPR column looked like the one-engine column (in the table of thrust settings) and as a result, they had just inadvertently performed the minimum climb gradient takeoff. FTE-1 revised his earlier report about the AOA, stating that the maximum AOA during the takeoff was 9.5 degrees, AOA at liftoff was 8.5 degrees, and pitch at liftoff was 8.1 degrees. FTE-1 conferred with TM-4, who stated that the column (data column of thrust values) that FTE-1 said he was using represented the one-engine EPR value split over two engines, and it contained the correct values. The column labeled "EPR one-engine" was the setting to use with one engine operating and it was just a reference. P-3 then said there were not two values, the two-engine column was just the value from the single-engine column divided across the two engines. He commented that because the thrust at liftoff was 1.196 and the minimum thrust was 1.18, he believed they had just done the most difficult maneuver in the series for test card 1. FTE-1 and the pilots agreed to use a thrust setting that incorporated a 15% margin for the next run and reduce thrust to the target setting at 90 knots instead of 80 knots.

(Card 1B repeat -L&R PWR: two eng min, target pitch 7-8 degrees)
[1406 GMT]

Winds: 255 at 1.1
Selected $\mathbf{V_2}$: 143 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: (not verbalized)
Selected EPR: 1.26

A margin of 15% was added to the minimum T/W ratio. The crew confirmed a pitch target of 7 to 8 degrees. Shortly after liftoff P-3 called "there's my 143, coming back on the pitch." About 10 seconds later he stated, "there's 143 knots, I'm going to check the flight control feel." He added that the pitch attitude was about 10.5 degrees.

After the run, FTE-1 said they were lifting off at 8.5 to 9 degrees (AOA) and he did not think they should target more than 9 or 10 degrees of pitch because they wanted to stay below 10.5 degrees of AOA. FTE-1 reported that on this run, the maximum AOA below 50 feet was 9.2 degrees. He added that it went down to 7.9 degrees as they accelerated. P-3 said the airspeed got up to 146 or 148 knots and then he started a gradual pull up to 10.5 to 11 degrees of pitch. He added that 10 to 11 degrees of pitch was probably a good number during the climb. The liftoff EPR was 1.24.

(Card 1C L&R PWR: two eng min T/W, target pitch 8 to 9 degrees)
[1415 GMT]

OAT: 9 deg C
Winds: 159 at 1.9
Selected $\mathbf{V_2}$: 143 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: (not verbalized)
Selected EPR: 1.26

FTE-1 said they would do this run with a little higher pitch target, 8-9 degrees, using the same EPR setting of 1.26. During the maneuver, while the airplane was at 143 knots, P-3 said 10.5 to 11 degrees of pitch and it was "still accelerating pretty good." He then called a speed of 147 knots, followed by call of 11 degrees of pitch, and then another speed callout of 143 knots. After the maneuver, FTE-1 said that the pitch at liftoff was 8.9 degrees. FTE-4 asked what the target pitch was for this run, so that she could ensure that she was logging it correctly. She noted that the AOA was between 8.9 and 9.2 degrees.

(Card 1D L&R PWR: two eng min T/W, target pitch 9 to 10 degrees)
[1430 GMT]

Winds: 063 at 1.2
Selected $\mathbf{V_2}$: 140 knots
Selected $\mathbf{V_{REF}}$: 156 knots
Weight: (not verbalized)
Selected EPR: 1.25

P-3 decided to target 10 degrees of pitch. P-3 asked if the speeds were to remain unchanged. FTE-4 said yes, and P-3 asked her to interpolate the speeds using the speed tables. During the maneuver, P-1 remarked that pitch was 10 degrees and AOA had gone up to 10.1 degrees during the rotation and then decreased to 9.7 degrees at liftoff. Just after P-3 called 20 feet AGL, he said "there's my 140" and then indicated that he was going to "go back" to capture "that." He then called a speed of 142, and FTE-4 then advised that the pitch was reaching 11.5 to 11.8 degrees. P-3 acknowledged the pitch, and stated that he is trying to capture $\mathbf{V_2}$. FTE-1 reported that the pitch attitude at liftoff was 9.6 degrees. He also noted that the T/W was "point one three." [7]

[7] The crew uses a mixed nomenclature when referring to the thrust over weight ratio (T/W). At times, they specify numbers less than 1, such as "point one three" which represents the thrust value in pounds, divided by the aircraft weight in pounds. Other times, they specify numbers greater than 1, such as "one point one three" which appears to represent the thrust value in pounds, divided by the aircraft weight in 10s of thousands of pounds.

Card 1E L&R PWR: single eng min T/W, target pitch 9 to 10 degrees)
[1445 GMT]

Winds: 010 at 2.5
Selected $\mathbf{V_2}$: 140 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: (not verbalized)
Selected EPR: 1.21

The on-board test crew queried TM-1 and TM-4 about the conditions they should use for this run. TM-1 asked them to perform the run using a minimum T/W of 0.11 with a 10 degree pitch target at flaps 20 and a static EPR setting of 1.21 (target 1.19 at liftoff) on both engines with no margin. P-1 observed that the takeoff pitch was about 10 degrees and the AOA was between 9.9 and 10.1 degrees. P-3 indicated that he captured $\mathbf{V_2}$. FTE-1 reported that it looked like a good run, T/W was "1.1".

(The crew then proceeded to Test Card 2)

(Card 2A L&R PWR: two eng min T/W plus (15%), target pitch 8 to 9 degrees)
[1457 GMT]

Winds: 044 at 2.2
Selected $\mathbf{V_2}$: 143 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: (not verbalized)
Selected EPR: 1.22

FTE-1 directed the pilots to target 8 to 9 degrees of pitch. The crew discussed whether or not to use 11.5 degrees or 11 degrees as the "knock-it-off" AOA, they ultimately chose to use 11 degrees. P-1 noted that an AOA of 11.7 is the shaker for flaps 10. FTE-1 asked if they should use 11.5 for the knock-it-off AOA, and P-1 says yes. Later, P-3 said that based on a stick shaker activation of 11.7, they should use 11 degrees as the knock-it-off AOA. P-3 asked FTE-1 and FTE-4 what the maximum AOA was on the previous run. FTE-4 responded that it was 10.2 degrees. P-1 added that it was "toggling" between 9.8 and 10.1 degrees. FTE-1 reported that it was 9.8 degrees at liftoff. The selected static EPR setting was 1.22 (targeting 1.20 at liftoff). FTE-4 provided a $\mathbf{V_2}$ speed of 142.3 knots, they selected 143 knots.

During the run, the highest speed called by P-3 was 145.5 knots. He indicated that he maintained about 13 degrees of pitch during the climb. After the run, FTE-1 reported that at liftoff, both the pitch and AOA were 9.3 degrees, and the maximum AOA was 11 degrees. P-3 reported that there was a "little bit of a bobble" during the initial part of the run. FTE-1 stated that the T/W was "one one five."

(The crew decided not to perform Card 2B.)

(Card 2C L&R PWR: two eng min T/W, target pitch 9 to 10 degrees)
[1511 GMT]

OAT: 6 deg C
Winds: 068 at 3.9
Selected $\mathbf{V_2}$: 142 knots
Selected $\mathbf{V_{REF}}$: 150 knots
Weight: (not verbalized)
Selected EPR: 1.22

FTE-4 indicated that the $\mathbf{V_2}$ speed was the same for this run (142.3). They selected 142 for this card. FTE-1 stated that the target pitch for this run would be 9 to 10 degrees and P-3 said he would target 10 degrees. FTE-1 commented that he tried plotting the last run in pitch and it did not look different from the "up and away stuff."

During the climb, P-3 asked FTE-4 for a report on the status of the flight control system because he had observed a single stabilizer channel failure. P-3 asked for a flight control reset and P-1 reached down to reset it but it did not reset. The crew decided that the condition was safe and they would attempt another reset on the ground. FTE-1 reported that pitch was 9.8 degrees. During the landing rollout, P-1 said that he might have seen a maximum AOA of 11 degrees during the takeoff and it was "toggling."

P-3 asked what the next run would be. FTE-1 said the same EPR, but higher on the pitch, which would be 10-11 degrees.

FTE-1 reported that the AOA reached 11.5 degrees during the climb to 100 feet. P-3 indicated that he was using the shaker as the "trip point," and "it's still looking good."

(Card 2D L&R PWR: two eng min T/W, target pitch 10 to 11 degrees)
[1523 GMT]

Winds: 069 at 3.5
Selected $\mathbf{V_2}$: 142 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: 94,000 lbs
Selected EPR: 1.22

The crew chose a pitch target of 11 degrees. During the maneuver, a sound similar to stick shaker (and a change in the background color of the airspeed indicator – from black to red) occurred during a callout which indicated liftoff. The sound and color change occurred again during a callout of 50 feet AGL.

After the maneuver, FTE-1 reported that the T/W was "one two one" at liftoff, and the pitch at liftoff was 10.9, with no reduction (in pitch).

(It appeared the crew omitted or decided to skip Card 2E.)

(Card 2F L&R PWR: single eng min T/W, target pitch 10 to 11 degrees)
[1532 GMT]

OAT 9 deg C
Winds: 021 at 1
Selected $\mathbf{V_2}$: 140 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: (not verbalized)
Selected EPR: 1.17

The crew chose a target pitch of 10 to 11 degrees. During the maneuver, just after the "airborne" callout, a sound similar to stick shaker (and a change in the background color of the airspeed indicator – from black to red) occurred. During a callout of "2,000 feet remaining" P-3 aborted the maneuver due to trucks that were off the end of the runway ahead of the airplane, and due to the low climb gradient.

After the maneuver, the crew discussed the low climb gradient and the EPR setting. FTE-1 reported the pitch attitude "was right on 11" at liftoff.

FTE-1 asked the pilots if there was a stick shaker on this run, because he thought he had heard it at liftoff. The pilots responded that they didn't think so, and couldn't recall. P-3 said they did get a stick shaker on the "last run" (assumed to be Card 2D). P-1 commented that the shaker is "so benign", that "you can't hardly even tell."

(Card 2F1 (repeat of 2F) L&R PWR: single eng min T/W, target pitch 10 to 11 degrees)
[1540 GMT]

Winds: 334 at 2.2
Selected $\mathbf{V_2}$: 140 knots
Selected $\mathbf{V_{REF}}$: 150 knots
Weight: (not verbalized)
Selected EPR: 1.19

The crew chose a target pitch attitude of 10 to 11 degrees. Prior to liftoff, a sound similar to shaker (and a change in the background color of the airspeed indicator – from black to red) occurred and P-3 stated "little bit of shaker."(The sound and color change occurred several times during the climb to 80 feet)

After the maneuver, FTE-1 reported that the (liftoff) pitch was 10.9 degrees.

FLIGHT 083 V_{MU} Development (LIGHT), Roswell NM November 11, 2010

Notes:
Recording started at about 1300 GMT and ended at 1502 GMT.
All takeoffs are on runway 3 unless otherwise specified.
The Pilot In Command's (left seat) Head's Up Display (HUD) is down (deployed).
The PFD shown on display unit 1 is the 2/3rds PFD with the cross-pointer pitch reference and no flight path angle set line.

Crew for this flight:
P-3 was the Pilot In Command in the left hand seat.
P-1 was the Second In Command in the right hand seat.
FTE-1 was the lead Flight Test Engineer
FTE-4 was the 2nd Flight Test Engineer
TM-4 was the FTE in the telemetry trailer.

Test Cards
The Video Group documented the segments of this flight which related to the following test cards:

Card 1: Performance: Field: V_{MU} Development
(selected excerpts from the Test Description section)

- Flaps 10
- Weight: LIGHT
- CG: FWD LIM
- Set L&R PWR:MTO; release brakes.
- During the Initial ground acceleration and prior to 60 KCAS, set L&R PWR: target EPR for test T/W.
- At approximately 60 KCAS apply full aft control column. When aircraft begins to rotate, use control column to capture the target pitch attitude for the test condition and maintain through liftoff until out of ground effect or 100 AGL.

Card 2: Performance: Field: V_{MU} Development
(selected excerpts from the Test Description section)

- Flaps 20
- Weight: LIGHT
- CG: FWD LIM
- Set L&R PWR:MTO; release brakes.
- During the Initial ground acceleration and prior to 60 KCAS, set L&R PWR: target EPR for test T/W.
- At approximately 60 KCAS apply full aft control column. When aircraft begins to rotate, use control column to capture the target pitch attitude for the test condition and maintain through liftoff until out of ground effect or 100 AGL.

Summary of Video/Audio Recording

(Card 1A L&R PWR: AEO EPR, target pitch 10 to 11 degrees)
[1352 GMT]

OAT: 0 deg C
Winds: 279 at1.9
Selected V_2: 123 knots
Selected V_{REF}: 133 knots
Weight: 73,000 pounds
Selected EPR: 1.30 (trailer personnel not present when FTE-1 asked for concurrence on the EPR)

The crew chose a pitch target of 10 to 11 degrees. After the maneuver, FTE-1 reported 10.2 degrees of pitch at liftoff (and noted that the pitch did not decrease at all, the pilot continued to pull up, and that was good.

(Card 1B L&R PWR: OEI EPR plus 15%, target pitch 10 to 11 degrees)
[1404 GMT]

Winds: 284 at 2.1
Selected V_2: 123 knots
Selected V_{REF}: 133 knots
Weight: 72,000 pounds
Selected EPR: 1.14 (15% margin)

After the maneuver, P-3 asked if the run "makes the guarantee numbers that we want." FTE-1 indicated that his display screen was not producing some derived parameters that helped him determine the T/W, so he needed some time to compute them. He then said they were expecting to get a T/W of 1.1-ish, but he was comfortable using that number unless TM-1 needed a lower T/W. P-3 asked if TM-4 was discussing the T/W with TM-1, TM-4 confirmed that they were.

FTE-1 estimated that the T/W for this run was actually 0.11, and recommended that the next run reduce the EPR setting by 0.01 to 1.13. TM-4 indicated that based on the charts, they would need an EPR of 1.11, at liftoff. FTE-1 indicated that to account for the droop, they would need a static setting of about 1.12. The flight crew and TM-4 eventually concurred on using 1.13 at the selected static setting to have the power set " a little more" than the prediction.

No post run briefing was audible (to the video group) of the pitch attitude at lift off.

(Card 1C L&R PWR: OEI EPR, target pitch 10 to 11 degrees)
[1416 GMT]

Winds: 307 at 3.5
Selected $\mathbf{V_2}$: 123 knots
Selected $\mathbf{V_{REF}}$: 133 knots
Weight: (not verbalized)
Selected EPR: 1.13

During the takeoff, the airplane was "skipping" down the runway (as noted by the crew referencing the weight on wheels (WOW) indications). Shortly after liftoff, P-1 commented that AOA was just below 11 degrees. After the maneuver, FTE-1 reported 10.9 degrees of pitch (at liftoff).

(Card 2A L&R PWR: AEO EPR, target pitch 9 to 10 degrees)
[1423 GMT]

Winds: 337 at 2.2
Selected $\mathbf{V_2}$: 118 knots
Selected $\mathbf{V_{REF}}$: 129 knots
Weight: 70,000 pounds
Selected EPR 1.33 (target of 1.32)

FTE-1 noted that this run would not have an additive power setting margin, as none was needed for the all engine test condition, and he noted that they had "plenty of gradient" (TM trailer personnel confirmed the EPR setting). The crew decided to target 9 to 10 degrees of pitch. After the maneuver FTE-1 reported that pitch at liftoff was 8.6 to 8.9 degrees, and pitch was not increasing at the time.

(Card 2B L&R PWR: OEI EPR plus 15%, target pitch 9 to 10 degrees)
[1430 GMT]

Winds: 352 at 2.8
Selected $\mathbf{V_2}$: 118 knots
Selected $\mathbf{V_{REF}}$: 129 knots
Weight: 70,000 pounds
Selected EPR: 1.16 (target 1.15, with a 15% margin)

(TM trailer personnel confirmed the EPR setting)

The crew decided to target 9 to 10 degrees of pitch. After the maneuver, FTE-1 commented that they were getting a lot of "skipping along on that one gear…" He computed that the thrust at liftoff was 8400 lbs, and that the T/W for this run was "point one two" and their target T/W was "one one three." He advised that the EPR setting for the next run should not be reduced by more than .01 less than the previous (Card 2B) run.

The pitch and airspeed at liftoff were not reported.

(Card 2C L&R PWR: OEI EPR, target pitch 9 to 10 degrees)
[1442 GMT]

Winds: 341 at 3.2
Selected $\mathbf{V_2}$: 118 knots
Selected $\mathbf{V_{REF}}$: 129 knots
Weight: (not verbalized)
Selected EPR: 1.15

(TM trailer personnel confirmed the EPR setting)

The crew did not verbalize the pitch target value prior to the run, however P-3 called "capturing ten" during the maneuver. The pitch and airspeed at liftoff were not reported after the run.

P-3 asked FTE-1 if he wanted to repeat the two engine test (Card 2A), FTE-1 explained the problem with that run was that the pitch was slightly below the target attitude at the time of liftoff. The crew decided to repeat Card 2A.

(Card 2A1 L&R PWR: AEO EPR, target pitch 9 to 10 degrees)
[1449 GMT]

Winds: 343 at 6.4
Selected $\mathbf{V_2}$: 117 knots
Selected $\mathbf{V_{REF}}$: 129 knots
Weight: 69,000 pounds
Selected EPR: 1.31

(This run not was not performed because the winds were out of limits). The crew decided to defer this repeat until the following morning). The crew discussed the "usability" of the data from the previous Card 2A run. FTE-1 explained that the data were usable, but they had dropped the nose slightly after liftoff which they were not supposed to do for the test point. The crew discussed the difficulty and "dynamics" of trying to "catch it" (establishing and maintaining the target pitch at liftoff under these conditions).

FLIGHT 088 V_{MU} Development (MEDIUM) Roswell NM November 16, 2010

Notes:
Recording started at 1304 GMT and ended at 1527 GMT.
All takeoffs were on runway 21 unless otherwise noted.
The TM trailer personnel were on the radio but they were having problems receiving transmissions.
Card 2A was the first run of the day, during which a wing drop event occurred. This portion of the recording was transcribed verbatim. Transcription begins as the airplane is back taxiing on runway 21.

Crew for this Flight:
P-1 was the Pilot In Command in the left hand seat.
P-3 was the Second In Command in the right hand seat.
FTE1 was the lead Flight Test Engineer.
FTE3 was the 2nd Flight Test Engineer.
TM-4 was in the telemetry trailer.

Test Cards:
The Video Group documented the segments of this flight which related to the following test cards:

Card 2: Performance: Field: V_{MU} Development
(selected excerpts from the Test Description section)

- Flaps 20
- Weight: MEDIUM
- CG: FWD LIM
- Set L&R PWR:MTO; release brakes.
- During the Initial ground acceleration and prior to 60 KCAS, set L&R PWR: target EPR for test T/W.
- At approximately 60 KCAS apply full aft control column. When aircraft begins to rotate, use control column to capture the target pitch attitude for the test condition and maintain through liftoff until out of ground effect or 100 AGL.

Card 4: Performance: Field: Takeoff Pitch Attitude Development OEI
(selected excerpts from the Test Description section)

- Flaps 20
- Weight: LIGHT
- CG: FWD LIM
- Set L&R PWR:MTO; release brakes.
- At Target $\mathbf{V_{EF}}$ ($\mathbf{V_1}$ -___) fail RH engine using a throttle chop.
- Rotate at $\mathbf{V_R}$ at a normal rotation rate (3-5 deg/sec) to target pitch attitude.
- Maintain target pitch attitude until $\mathbf{V_2}$ is achieved
- Adjust pitch attitude to maintain $\mathbf{V_2}$ to gear retraction or 400 ft AGL.

Card 5: Performance: Field: Takeoff Pitch Attitude Development AEO
(selected excerpts from the Test Description section)

- Flaps 10
- Weight: LIGHT
- CG: FWD LIM
- Set L&R PWR: as specified.
- Rotate at $\mathbf{V_R}$ at a normal rotation rate (3-5 deg/sec) to target pitch attitude.
- Maintain target pitch attitude until $\mathbf{V_2}$ +10 is achieved.
- Adjust pitch attitude to maintain $\mathbf{V_2}$ +10 to gear retraction or 400 ft AGL.

Card 6: Performance: Field: Takeoff Pitch Attitude Development OEI
(selected excerpts from the Test Description section)

- Flaps 10
- Weight: LIGHT
- CG: FWD LIM
- Set L&R PWR: MTO, release brakes.
- At Target $\mathbf{V_{EF}}$ ($\mathbf{V_1}$ -___) fail RH engine using a throttle chop.
- Rotate at $\mathbf{V_R}$ at a normal rotation rate (3-5 deg/sec) to target pitch attitude.
- Maintain target pitch attitude until $\mathbf{V_2}$ is achieved.
- Adjust pitch attitude to maintain $\mathbf{V_2}$ to gear retraction or 400 ft AGL.

Summary of Video/Audio Recording

(Card 2A L&R PWR: AEO EPR, target pitch 9 to 10 degrees)
[1329 GMT]

Winds: 139 at 1.5
Selected $\mathbf{V_2}$: 119 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: (not verbalized)
Selected EPR 1.33

(Beginning of transcribed section)

Time	Source	Comment
1326:37	P-1	ok VMU uhh, as soon as airspeed's- I guess you're gonna pull em back at about 60 knots?
1326:42	P-3	yes sir.
1326:43	P-1	ok go ahead and get into your position… we'll uh, set power, you'll mark it with the tape, and everybody's ready to go we'll go ahead and-
1326:51	FTE-1	we're ready in the back here.
1326:52	P-1	-do a static run up * brake release… and then we'll go airspeed alive, I'll put the yoke back in my lap, we're shootin for 10 degrees?
1327:01	FTE-1	nine to ten, yeah.
1327:02	P-1	nine to ten, ok…. and no gear retraction until we're definitely airborne.
1327:08	FTE-1	yeah.
1327:08	P-1	I don't think it will be an issue.
1327:10	FTE-1	I don't need the gear on this one, you can just leave it down.
1327:12	P-1	ok that's good. that works. then I don't have to worry about it.
1327:14	P-3	and we still capture, you want us to capture the $\mathbf{V_2}$?
1327:17	FTE-1	yeah lets capture $\mathbf{V_2}$ just to see what kinda trim speed we're getting.
1327:19	P-1	and, $\mathbf{V_2}$ is?
1327:21	P-3	one nineteen.
1327:23	P-1	* * ok cool.
1327:24	FTE-1	or you could actually, it's all engines, so we could do a V2 plus ten if you want…. Let's uh, let's do that.
1327:30	P-1	$\mathbf{V_2}$ plus ten?
1327:21	FTE-1	yeah, just try to capture that.
1327:33	P-1	ok.
1327:34	FTE-1	mainly just hold the pitch attitude till a hundred feet, and I'll call that, and then you can –
1327:40	P-1	ok.
1327:42	P-3	ok so hold the pitch attitude and let the airspeed just accelerate?
1327:46	FTE-1	right. no that's-
1327:47	P-1	till we get to a hundred feet.

Time	Source	Comment
1327:48	FTE-1	-you don't wanna- you don't wanna drop the nose.
1327:50	P-3	right. but, so you don't want us to capture V_2 plus ten.
1327:53	FTE-1	yeah, we were doing that on the climbout the last time with the engine out, but, lets skip that. we can just -
1327:55	P-1	you don't wanna do it? ok.
1327:59	FTE-1	just go to a hundred feet and then you can push the power up.
1328:01	P-1	and we're done.
1328:02	P-3	ok just hold pitch attitude.
1328:03	P-1	gotcha.
1328:03	FTE-1	yup.
1328:04	P-3	ok.
1328:05	P-1	all right man.
1328:12	P-1	get 'em one last wind check here (P-3).
1328:14	RDO-P-3	yup we will.
1328:15	P-1	* we're (doin).
1328:21	RAAS	on runway, two one.
1328:23	RDO-P-3	and Gulfstream weather, say winds?
1328:25	GWS	winds are one two five at one point seven.
1328:29	P-1	cool.
1328:36	RDO-P-3	thank you.
1328:38	P-3	ok, yall 'bout ready in the back?
1328:40	FTE-1	ready.
1328:40	FTE-4	ready.
1328:45	P-1	it's gonna be lots of power.
1329:06	P-1	ok. ready to go?
1329:08	P-3	that looks good, that looks good, flaps are twenty, trim is set, FT ENABLE (switch that allows the Flight Control Computer to accept the settings from the Flight Test Engineer console)
1329:12	FTE-4	tape set.
1329:13	P-1	guys ready?
1329:14	FTE-1	ready.
1329:15	P-3	and video? I don't know if you need it or not.
1329:17	FTE-4	yeah.
1329:18	RDO-P-3	tower Gulftest eight three we're ready for takeoff…runway two one, and if we could, do a teardrop and land back runway three.
1329:25	TWR	Gulftest eight three, not a problem runway two one, cleared for takeoff, and report right base for runway three.
1329:32	RDO-P-3	we'll report right base, for runway three.
1329:33	P-3	so a left turnout.
1329:34	P-3	okay and brake release at three five.
1329:39	P-1	your throttles.
1329:39	P-3	my throttles.
1329:41	P-3	power is set looks good airspeed's alive, sixty knots coming back power is set.

Time	Source	Comment
1329:49	P-3	eighty knots.
1329:52	P-3	ninety knots.
1329:54	P-1	it's getting *.
1329:55	P-3	one hundred.
1329:58	VID	(the airspeed indicator background color briefly changes from black to red. This is a low speed awareness indication. There was no discernible sound of stick shaker).
1329:59	FTE-1	whoa.
1329:59	FTE-4	whoa.
1329:59	VID	(P-3 moves both hands to yoke, then left hand to throttles)
1330:01	P-1	power.
1330:02	VID	(P-1 and P-3 both have hands on the throttles which appear to be full forward).
1330:06	P-1	positive rate.
1330:06		(end of transcribed section)

Summary of remainder of test run 2A

P-1 commented that he had overshot the target pitch. FTE-1 said that the maximum pitch was 12.9 to 13 degrees. P-1 replied that it was a "pretty good" pitch rate. FTE-1 commented that the maneuver was a difficult one to perform properly because they were lifting off as they rotated the airplane. P-1 said he had to start slowing down the pitch rate before reaching 10 degrees. He repeated his observation that they overshot the target pitch. FTE-1 said it was okay and asked P-1 if he wanted to perform a buildup before they proceeded on with the test cards. P-1 replied that the pitch rate had increased rapidly and caught him by surprise and he planned to catch it earlier next time, and he thought that it might require a little push. FTE-1 again noted that this was a "hard one to get" because they were lifting off as they rotated.

(Card 2A repeat L&R PWR: AEO EPR, target pitch 9 to 10 degrees)
[1336 GMT]

Winds: 137 at 1.8
Selected $\mathbf{V_2}$: 119 knots
Selected $\mathbf{V_{REF}}$: 129
Weight: (not verbalized)
Selected EPR: 1.33

P-1 successfully repeated card 2A, and FTE-1 commented that it was a perfect run.

(Card 3 was not performed)

(Card 4A OEI, Target Pitch 6 to 7)
[1344 GMT]

Winds: 108 at 2.5
Selected $\mathbf{V_1}$: 107 knots
Selected $\mathbf{V_R}$: 112 knots
Selected $\mathbf{V_2}$: 118 knots
Selected $\mathbf{V_{REF}}$: 129 knots
Weight: (not verbalized)
Selected EPR: (MTO, retard R throttle to idle at $\mathbf{V_1}$ - 20)

FTE-1 reported that the airplane lifted off at 6 or 7 degrees of pitch. P-1 said that he overshot the pitch by "a little" and FTE-1 said the pitch was reduced after liftoff. P-1 and FTE-1 agreed to repeat the test.

(Card 4A1 Repeat OEI, Target Pitch 6 to 7)
[1352 GMT]

Winds: 130 at 1.7
Selected $\mathbf{V_1}$: 107 knots
Selected $\mathbf{V_R}$: 112 knots
Selected $\mathbf{V_2}$: 118 knots
Selected $\mathbf{V_{REF}}$: 129 knots
Weight: (not verbalized)
Selected EPR: (MTO, retard R throttle to idle at $\mathbf{V_1}$ - 20)

FTE-1 commented that the test was good, and the peak AOA was 7.3 degrees.

(Card 4B OEI, Target Pitch 7 to 8)
[1400 GMT]

Winds: 081 at 1.8
Selected $\mathbf{V_1}$: 107 knots
Selected $\mathbf{V_R}$: 111 knots
Selected $\mathbf{V_2}$: 117 knots
Selected $\mathbf{V_{REF}}$: 129 knots
Weight: (not verbalized)
Selected EPR: (MTO, retard R throttle to idle at $\mathbf{V_1}$ - 20)

FTE-1 checked the V-speeds for the run and FTE-4 offered to look up the speeds for him. After the run, FTE-1 noted that peak pitch was 8.5 degrees and P-1's control input was a ramp input. FTE-1 noted that they were getting a clean liftoff with no bounce.

(Card 4C OEI, Target Pitch 8 to 9)
[1406 GMT]

Winds: 107 at 2.6
Selected $\mathbf{V_1}$: 107 knots
Selected $\mathbf{V_R}$: 111 knots
Selected $\mathbf{V_2}$: 117 knots
Selected $\mathbf{V_{REF}}$: 129 knots
Weight: (not verbalized)
Selected EPR: (MTO, retard R throttle to idle at $\mathbf{V_1}$ - 20)

FTE-1 said the peak pitch was 8.6 degrees.

(Card 5 was performed after Card 6)

(Card 6A OEI, Target Pitch 7 to 8)
[1414 GMT]

Winds: 219 at 0.4
Selected $\mathbf{V_1}$: 107 knots
Selected $\mathbf{V_R}$: 111 knots
Selected $\mathbf{V_2}$: 123 knots
Selected $\mathbf{V_{REF}}$: 129 knots
Weight: (not verbalized)
Selected EPR: (MTO, retard R throttle to idle at $\mathbf{V_1}$ - 20)

The crew decided to target 8 degrees of pitch. FTE-1 said column force was 43 pounds, the peak pitch was 8.6 degrees, $\mathbf{V_R}$ was 111.5 knots and speed at 35 feet was 148 knots. He remarked that it was "definitely not the right pitch attitude" (it was unclear what FTE-1 was referring to here. He may have been indicating that this pitch attitude would not result in the intended $\mathbf{V_2}$).

(Card 6B OEI, Target Pitch 8 to 9)
[1420 GMT]

Winds: 116 at 1.5
Selected $\mathbf{V_1}$: 107 knots
Selected $\mathbf{V_R}$: 111 knots
Selected $\mathbf{V_2}$: 123 knots
Selected $\mathbf{V_{REF}}$ 129 knots
Weight: (not verbalized)
Selected EPR: (MTO, retard R throttle to idle at $\mathbf{V_1}$ - 20)

The crew attempted to repeat the previous run (with the same speeds) while trying to attain a higher pitch attitude. FTE-1 deemed the run a success, with peak pitch of 8.6 degrees and maximum AOA of 8.5 degrees.

(Card 6C OEI, Target Pitch 9 to 10)
[1432 GMT]

Winds: 074 at 3.1
Selected $\mathbf{V_1}$: 107 knots
Selected $\mathbf{V_R}$: 111 knots
Selected $\mathbf{V_2}$: 123 knots
Selected $\mathbf{V_{REF}}$ 129 knots
Weight: (not verbalized)
Selected EPR: (MTO, retard R throttle to idle at $\mathbf{V_1}$ - 20)

FTE-1 reported that peak pitch was 9.1 degrees, peak AOA was 8.7 degrees, and rotation occurred at 112 knots. The speed achieved at 35 feet AGL was 138 knots. P-1 asked if the column force was acceptable. FTE-1 said it was "a little light" at 37 pounds.

(Card 5A AEO, Target Pitch 9 to 10)
[1442 GMT]

Winds: 079 at 2.6
Selected $\mathbf{V_1}$: 107 knots
Selected $\mathbf{V_R}$: 111 knots
Selected $\mathbf{V_2}$: 123 knots
Selected $\mathbf{V_{REF}}$: 129 knots
Weight: (not verbalized)
Selected EPR: MTO

FTE-1 reported that the takeoff was "good." The (peak) pitch was 9.6 degrees and column force was 43 pounds, and the $\mathbf{V_R}$ was 111.2 knots. The peak AOA was 8 degrees. Speed at 35 feet was 147 knots.

(Card 5B(AEO, Target Pitch 10 to 11)
[1454 GMT]

Winds: 114 at 2.6
Selected $\mathbf{V_1}$: 107 knots
Selected $\mathbf{V_R}$: 111 knots
Selected $\mathbf{V_2}$: 123 knots
Selected $\mathbf{V_{REF}}$: 129 knots
Weight: (not verbalized)
Selected EPR: MTO

FTE-1 was satisfied with the run. He reported that peak pull force was 47 pounds. P-1 observed that there was still "a little bit of a bobble." FTE-1 said the pitch at liftoff was 10.3 degrees, $\mathbf{V_R}$ was 111.9 knots, and he observed that the pitch "bobbled" down to 9 degrees and then back up to 10 degrees, during the takeoff.

(Card 5C AEO, Target Pitch 11 to 12)
[1459 GMT]

Winds: 030 at 0.3
Selected $\mathbf{V_1}$: 107 knots
Selected $\mathbf{V_R}$: 111 knots
Selected $\mathbf{V_2}$: 123 knots
Selected $\mathbf{V_{REF}}$ 129 knots
Weight: (not verbalized)
Selected EPR: MTO

FTE-1 reported that stick force was 43 pounds, pitch was 11.0 degrees, and $\mathbf{V_R}$ was 111.9 knots.

FLIGHT 111, Takeoff Technique Development, Birmingham, AL, February 13, 2011

Notes:
Recording started at 1334 GMT and ended at 1550 GMT.
All takeoffs were on runway 6 unless otherwise noted.
There was no telemetry trailer at Birmingham.

Crew for this Flight:
P-3 was the Pilot In Command in the left hand seat.
P-2 was the Second In Command in the right hand seat.
FTE-1 was the lead Flight Test Engineer.
FTE3 was the 2nd Flight Test Engineer.

Test Cards:
The Video Group documented the segments of this flight which related to the following test cards:

Card 3: Performance: Field: Takeoff Rotation Rate Development Low T/W
(selected excerpts from the Test Description section)

- Flaps 20
- Weight: HEAVY
- CG: FWD LIM
- Set L&R PWR: MTO
- At target $\mathbf{V_{EF}}$ ($\mathbf{V_1}$-20), set L&R PWR: target EPR for test T/W.
- Rotate at $\mathbf{V_R}$ at target rotation rate to __9__ pitch attitude.
- Maintain target pitch attitude until $\mathbf{V_2}$ is achieved.
- Adjust pitch attitude to maintain $\mathbf{V_2}$ to gear retraction or 400 ft AGL.

Summary of Video/Audio Recording

At the start of the recording, the airplane was stopped and P-3 performed two practice pulls on the control column. The left PFD was set to a synthetic vision display format with cross pointer pitch reference and the right PFD format was set to 2/3 PFD. The left side HUD was not down. P-3 performed 7 practice pulls on the control column during the taxi to runway 6.

(Card 3A – Overspeed stick force variation, stick force 45-55lb, VR+4)
[1338 GMT]

Winds: calm (as reported on landing)
(V-speeds were set prior to the start of the recording)
Selected $\mathbf{V_1}$: (not verbalized)
Selected $\mathbf{V_R}$: (not verbalized)
Selected $\mathbf{V_2}$: (not verbalized, 139 knots was set on the SMC panel)
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: (not verbalized)
Selected EPR: MTO, then 1.21 at $\mathbf{V_1}$ – 20

P-3 performed two additional "practice" pulls on the control column while in position on runway 6.

Shortly after calling 80 knots, P-2 set the throttles to the target EPR setting. P-3's hands were loosely cupped around the control yoke horns. When P-2 called "rotate," P-3 grabbed and pulled the control yoke, and pitched the airplane to about 10 degrees. The PLI appeared on the PFD, and as it started moving upward, P-3 began tracking its increase in pitch. P-3 said there was "still a little bobble" while attempting to fly the target pitch. P-2 did not retract the landing gear, and P-3 instructed him to do so. P-3 told P-2 that he should raise the gear as soon as all three landing gear wheel indications go to air mode.

After the maneuver, FTE-1 reported that the control column force was about 46 lbs and was held initially for 1.5 – 2 seconds and then reduced to 8 lbs, and then increased to 38 lbs. $\mathbf{V_R}$ was 136.2 knots. FTE-1 said that the takeoff was a "little fast" on the speed during climbout, at 141 knots (which was 2 knots faster than $\mathbf{V_2}$ set on the SMC). FTE-1 reported that the maximum normalized angle of attack was 0.84 at the end, which was "pretty" close to the stick shaker. P-3 said that he was "just under" the PLI. FTE-1 said the time from rotation to liftoff was about 4 seconds and the time from liftoff to 35 feet above ground level was about 7 seconds. He added that it looked like a "pretty good" run. FTE-1 suggested trying to "hold it in shorter" (the initial control column input). FTE-1 and P-3 discussed having to wait for the airplane to respond after the initial input, and P-3 indicated that he would try to start reducing the column input when the airplane reached 5 degrees of pitch attitude.

FTE-1 said that on this run, the column input started to reduce at about 6 degrees of pitch. He further stated that that the forces were "a little" heavy (the $\mathbf{V_2}$+10 trim setting) and he would like to use a little less trim. FTE-1 asked P-3 to pull over so that he could look up the speeds for the next run, which they decided would be a repeat of test card 3A. P-3 performed 8 practice column pulls.

FTE-1 provided the V-speeds and EPR setting. P-2 noted that he was unable to set the test target of $\mathbf{V_R}$+4 on the SMC. [In this case, $\mathbf{V_R}$+ 4 was 136 knots. With the $\mathbf{V_2}$ set at 138 knots, the SMC would not permit a $\mathbf{V_R}$ setting higher than 134 knots.] P-2 and P-3 resolved this by indicating the $\mathbf{V_R}$ would be set lower than the intended value on the SMC, but the verbal callout for "rotate" would occur at the correct airspeed value.

P-3 told P-2 to put the flight control page up, so that he (P-2) could use the combined weight on wheels indicator as a reference for when to retract the landing gear.

P-3 asked for any comments from the FTEs, and FTE-1 suggested to "take it out a little earlier" (start reducing the initial control column input earlier) and "see what it does." FTE-1 said that they previously had a 4 second time duration from rotate to liftoff, which was "pretty good." He further stated "I guess that's mainly what the rotate piece is doing for us…we were getting the speed at liftoff", and he indicated he would like to get "a little faster on that."

(Card 3A repeat – Overspeed stick force variation, stick force 45-55lb, VR+4)
[1353 GMT]

Winds: calm
Selected $\mathbf{V_1}$: 129 knots
Selected $\mathbf{V_R}$: 132 knots (test card calls for rotation at $\mathbf{V_R}$+4)
Selected $\mathbf{V_2}$: 138 knots
Selected $\mathbf{V_{REF}}$: 150 knots
Weight: (not verbalized)
Selected EPR: MTO, then 1.21 at $\mathbf{V_1}$ – 20

During the maneuver, P-3 initially pitched the airplane to about 9 degrees. Once the PLI was in view, P-3 kept the pitch attitude about 1-2 degrees below the PLI. FTE-1 reported that the column force was about 10 lbs while at $\mathbf{V_2}$.

After landing, FTE-1 reported that the initial pull force was 45 pounds, it was relaxed to 18 pounds, and then it was pulled in "a little" and then pushed "a little bit" and then "pulled back in". FTE-1 said that he was trying to figure out what to do with the pitch attitude. The time from rotation to liftoff was about 5 seconds. FTE-1 said "I think if you pull harder we're just gonna make it worse." P-3 agreed. FTE-1 said "the idea was, is go faster so the airplane lifts off in the rotation, we're still not lifting off, uh you hit the pitch attitude well before… a second before lift off."

P-3 said "unless you make your $\mathbf{V_2}$ faster." He further added that he could lift off closer to $\mathbf{V_2}$ (by trying the $\mathbf{V_R}$+6 knots variant of the test card) but he then noted that the card they just completed (rotating at $\mathbf{V_R}$+4 knots), was already within 2 knots of $\mathbf{V_2}$. FTE-1 said the peak pitch on this run was 9.6 degrees, and the speed at rotation was between 135 and 136 knots, (he indicated that the pilots should continue to use the same callout technique for $\mathbf{V_R}$). He further stated "I just think what's gonna happen is, is you pull harder we're just gonna be to that pitch attitude sooner and sit there at 9 degrees and have more overshoot, because there is nowhere to go. The airplane isn't lifting off…"

P-2 said that in the (F-18) Hornet, if you rotated too early, the drag would increase and "it delays it actually" (the takeoff). P-3 said "we are trying to increase the speed a little bit to even get it better, but there is not enough energy." P-3 said that the increase in induced drag does not help.

While looking at the data for airspeed after the rotation on this run, FTE-1 explained that the speed in the air data "goes flat because of that droop in altitude" (FTE-1 is likely referring to the characteristic static pressure drop which occurs during rotation, which causes a "droop" in altitude data). P-3 asked FTE-1 if he wanted them to stop for further discussion, FTE-1 said yes.

FTE-1 said that he had been thinking "if we pull harder I think we're just going to have to go faster… the idea is, is that if you go fast enough we should lift off in the rotation not get to the pitch attitude, but then we go so fast there is no way I can get uh, you know, capture $\mathbf{V_2}$, if I'm hittin it before liftoff." P-3 said that he reached 142 knots. FTE-1 said that he doesn't see how that is going to help them, and that he was trying to decide what they should do next.

FTE-1 asked if P-3 was comfortable performing the next takeoff at a higher control column force. P-3 said yes. FTE-1 suggested that they do one, but he thought there would be more overshoot. He indicated that they would still try to capture 9 degrees of pitch but they would get there faster. FTE-1 said to use $\mathbf{V_R}$ + 4. P-2 asked what the column force would be, and P-3 indicated 55-65 lbs, and P-3 practiced 10 column pulls.

FTE-1 provided V-speeds. P-2 said that it's not possible to set $\mathbf{V_R}$ at 135 and $\mathbf{V_2}$ at 137 in the SMC (because the values are too close together). P-2 set the V-speeds in the right side SMC. P-3 advised to enter $\mathbf{V_2}$ as 137 knots and $\mathbf{V_R}$ as 133 knots, because that provided a 2 knot lead for the callout of the intended $\mathbf{V_R}$ (as they had been doing). P-3 practiced 3 pulls while FTE-1 advised him to hold the pull in for about a second instead of 1.5 seconds. P-3 said he had to generate some rate to do that.
FTE-1 revised the EPR setting to 1.21. P-3 practiced 3 additional pulls and said "you wanna try it", and FTE-1 replied, "I'm ready." During the taxing to the runway 6, P-3 performed 3 practice pulls on the control column.

(Card 3B – Overspeed stick force variation, stick force 55-65lb, VR+4)
[1410 GMT]

Winds: calm
Selected $\mathbf{V_1}$: 128 knots
Selected $\mathbf{V_R}$: 131 knots (test card calls for rotation at $\mathbf{V_R}$+4)
Selected $\mathbf{V_2}$: 137 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: 95,000 lbs
Selected EPR: (MTO, then 1.21 at $\mathbf{V_1}$ – 20)

P-3 continued to use a synthetic vision display format with cross pointer pitch reference and P-2 continued to use a 2/3 display format. The left side HUD remained stowed.

During rotation, P-3 began to release column input when passing 5 degrees of pitch. As he approached 8 degrees of pitch, he moved the column slightly forward to arrest the pitch at 8 degrees with a slight bobble. He paused and began to track the pitch attitude at about 1 degree below the PLI.

P-2 did not raise the landing gear immediately after the positive rate of climb was established. P-3 noted this, and explained to P-2 which test segments of the takeoff sequence should have the gear up, vs. down.

P-3 noted that the airplane "generates a good rate."

After landing, FTE-1 reported that the run looked "pretty good" and the stick force values looked like the pilot was "pumping it there." P-3 said he was "trying to do a slow capture, and the pitch rate stopped about, oh, eight, and had to had to pull up to get to the nine" (degrees of pitch attitude).

P-3 said "it (the 55 lb to 65 lb pull force) generates a good pitch rate." P-3 asked FTE-1 if he wanted to "pull over and talk about it" and FTE-1 said yes.

FTE-1 reported that the instantaneous pitch rate reached almost 7 degrees/second and it was "coming up fast." P-3 asked if they lifted off any better, FTE-1 replied that the time (from rotation to liftoff) was "a lot better."

At about 1420 GMT, FTE-1 asked FTE-4 to exit the airplane to check the tires while the airplane was stopped on the taxiway. During that time, FTE-1 reported that the column force was 62 to 65 pounds of pull, and it was held in for about 1 second, and then it started relaxing to 10 pounds and then pulled to about 40 pounds and captured 8.2 degrees of pitch. P-3 agreed, and added that he then pulled it back to 9 and continued the pull to capture $\mathbf{V_2}$. FTE-1 said the speed was a "little fast" on the lift off but it was a good run other than capturing the pitch.

FTE-1 said that the timing was about 3.5 seconds to liftoff and that was a "good time" and still "about 7 (seconds) to 35 feet" above ground level. FTE-1 asked if they wanted to try the next stick force and P-3 agreed. FTE-1 said they would perform the remainder of the cards, and then he would spend some time reviewing the test data.

P-2 asked P-3 about the technique P-3 had been using for force input and asked if he was relaxing it just as the pitch got to nine degrees. P-3 said no, instead the relaxing of input began at about 5 degrees or so, he added "then it's like (he gestured with his hands to mimic control column inputs) ok and you capture it, but then it's like ok too much, you know there's not, its, unless I go really slow, and then it's like ok, I'm gonna capture it there."

At about 1422 GMT, FTE-4 entered the airplane and reported the tire condition. P-2 and FTE-1 then exit the airplane to check the tire condition.

At about 1425 GMT, P-2 and FTE-1 re-entered the airplane.

At about 1428 GMT, FTE-1 indicated that he was trying to decide how to proceed with the next run. He said that the previous run was a little fast on the speed at that rotation rate, and asked the pilots if they wanted to try a faster rotation rate, or if they thought the rate was pretty good. He added that the time from rotation to liftoff was good. P-3 stated that the rate was "pretty quick",

and he inquired about column force on the previous run. FTE-1 replied that it was 65 pounds at the peak. P-3 then practiced 3 column pulls.

P-3 told FTE-1 that it was FTE-1's call, and added "there is not that much more force into it", and he was not sure how much more displacement would result from an additional 5-10 pounds of column force.

FTE-1 initially decided that they should repeat the last test card, changing only the airspeed to something slower. He subsequently decided that they should instead progress to the next card, which kept the speed the same and changed only the column force (to 65-75 pounds) in order to finish out the test sequence. P-3 agreed. FTE-1 also said that they could perform additional testing at Roswell if they didn't complete it at Birmingham.

FTE-1 provided the V-speeds and EPR setting, and advised the pilots to pull back "like you were doing before 110 or whatever" (speed at which to reduce the throttle to the target EPR setting). P-2 entered the V-speeds on the right SMC. P-3 practiced 4 column pulls.

At about 1433 GMT the taxi to runway 6 began. For this run, the left PFD was set to a 2/3 format with a cross pointer pitch reference. The HUD remained stowed. P-3 practiced 3 column pulls.

(Card 3C – Overspeed stick force variation, stick force 65-75lb, VR+4)
[1436 GMT]

Winds: calm
Selected $\mathbf{V_1}$: 127 knots
Selected $\mathbf{V_R}$: 131 knots (test card calls for rotation at $\mathbf{V_R}$+4)
Selected $\mathbf{V_2}$: 137 knots
Selected $\mathbf{V_{REF}}$: 148 knots
Weight: (not verbalized)
Selected EPR: (MTO, then 1.21 at $\mathbf{V_1}$ – 20)

After lining up on the runway, P-3 performed one additional practice pull and reminded P-2 to raise the landing gear immediately after the WOW indicator indicated airborne mode.

After the maneuver, during climbout while still at the target EPR setting, P-3 asked what the current column force was (at $\mathbf{V_2}$), he then stated "there's a little bit of shaker right there" just after the airspeed indicator briefly changed color from black to red. P-3 then advanced the throttles. FTE-1 replied that the column force was about 15 lbs.

P-3 said he "shouldn't have tried something new." He said that he was using synthetic vision (SV) earlier, and the 2/3 display he was using now for this run, was a better format to see rates (pitch rates during rotation). P-2 asked if he liked the PFD 2/3 format better and P-3 said yes. P-3 said that on the SV, "things are moving so fast" due to the expanded scale. He added that when using the SV, "you can't anticipate as well."

After landing, FTE-1 reported that the peak column force was 69 lbs, and then it relaxed down to 11 lbs. The initial pitch reached 9.4 degrees and then reduced to 8.5 at liftoff. FTE-1 said that the airplane rotated at 134.3 knots. P-3 said that the run was better on speed control. FTE-1 said that the speed was "a little fast" averaging 138 knots. P-3 said he was flying right at 0.82, 0.83 normalized angle of attack, and they "hit shaker" with that "little bit of turbulence bobble." FTE-1 advised that he didn't think they should reduce the speed much, and that they should repeat the same run again.

P-3 asked what needed to be done differently for the repeat run. FTE-1 suggested potentially trying to take the control column input out a little earlier, and then asked P-3 what he thought they should do to try and keep the pitch from bobbling.

FTE-1 reported that on the previous run, it was less than 3.5 seconds from rotation to lift off and about 7 seconds to 35 feet above ground level, which was a "pretty good run."

FTE-1 suggested they could try +3 ($\mathbf{V_R}$+3) on the speed with the same technique, and then asked P-3 what he thought. FTE-1 stated "do you think? cause we should be slower? I mean you're pretty much capturing the speed, do you think uh you lifted-you saw a speed after you got to the pitch attitude, or?"

P-3 said “it’s just about right there… as soon as I got to the pitch attitude I looked over and we were like 138, so, you know as it went through and I captured it and I look over and its 138 so I was like, I’m there. So then I gotta continue the pull.”

FTE-1 told P-3 “if you think the speeds are lining up that you can capture $\mathbf{V_2}$ then I would keep it as is, I guess.” FTE-1 said he would keep the rotation speed at $\mathbf{V_R}$+4 knots.

At about 1447 GMT, FTE-4 exited the airplane to check the tires.

P-2 asked if the V-speeds would remain unchanged. FTE-1 replied that all the speeds would decrease by one knot. P-3 told P-2 to set $\mathbf{V_2}$ at 136 knots and set the $\mathbf{V_R}$ as “high as he can.” P-3 said that there are margins in the software that have range limits for setting the speeds, which prevents them from setting $\mathbf{V_R}$ and $\mathbf{V_2}$ too close together The crew noted that despite this, it had worked out well so far because setting the $\mathbf{V_R}$ at a slightly slower value than the test target had allowed them a little more time to coordinate the callout sequence during takeoff, such that they actually rotated at the test target speed.

P-3 asked if the actual $\mathbf{V_R}$ speed they had been getting was close to the test target speed, and FTE-1 agreed and said it was within 1 knot. FTE-1 said that the airspeed indications P-3 and P-2 were seeing, were lagged due to a data transport delay, and the values were smoothed in the Planeview software on the pilot’s displays. FTE-1 said that his display did not reflect the lag. P-2 says that the speed on the tape seemed to linger and stagnate “a little bit.”

At about 1448 GMT, FTE-4 re-entered the airplane.

P-3 practiced 5 column pulls.

The taxi to runway 6 began at about 1451 GMT.

P-3 practiced 3 column pulls.

(Card 3C Repeat– Overspeed stick force variation, stick force 65-75lb, VR+4)
[1456 GMT]

Winds: calm
Selected $\mathbf{V_1}$: 126 knots
Selected $\mathbf{V_R}$: 130 knots (test card calls for rotation at VR+4)
Selected $\mathbf{V_2}$: 136 knots
Selected $\mathbf{V_{REF}}$: 147 knots
Weight: 93,000 lbs
Selected EPR: (MTO, then 1.20 at $\mathbf{V_1}$ – 20) (EPR was actually set at 1.21 during the run).

During the run, P-3 rotated and attained a pitch attitude of about 10-11 degrees, and remained at or below the PLI. About 20 seconds after the rotation, the airspeed indicator flickered from black to amber. While climbing, P-3 said it "even gets fast." After transferring control to P-2, he said he "pulled a little higher than 9 (degrees) but it still got fast in trying to pull into it and keep that (speed)." He added that he "went slow to try to capture 9 (degrees) (while motioning with his hands mimicking a relax of the column input) and then it was getting fast, so it was just like ok just keep goin."

FTE-1 stated that for the next run they should reduce the target $\mathbf{V_R}$ by two knots.

After landing, FTE-1 reported that the initial column force was 70 pounds, which was "good," it relaxed to 13 lbs and then increased to about 33 lbs at liftoff. The peak pitch was a "little high" with 10.3 degrees, which reduced to 9.2 degrees at liftoff. The time from rotation to liftoff was about 3.5 seconds, and the time from liftoff to 35 feet AGL was about 6.5 seconds.

FTE-1 further stated that they "nailed" the $\mathbf{V_R}$ speed of 134 knots. P-3 noted that the liftoff speed was higher than the $\mathbf{V_2}$ speed of 136 knots. FTE-1 said the speed was initially held at 137 knots, and increased to 140 knots at about 10 feet AGL. P-3 said that he was holding the pitch attitude and was trying to capture it. FTE-1 said that technique wise, the stick force was ok.

FTE-1 asked P-3 if he could convince the FAA certification official that this is a "normal technique." P-3 said they would need to modify it "slightly" by "…pull, until it starts rotation and then capture the pitch attitude, and we can see how it works and then capture speed." FTE-1 said "lets try that at $\mathbf{V_R}$ minus 2,[8] so pull a lot in but then let off, that may help with the overshoot and see what kind of time we get."

FTE-1 said he would like to complete the "$\mathbf{V_R}$ minus 2" run twice, and he had planned to do a run at $\mathbf{V_R}$ but he didn't know if they wanted to actually perform a run using $\mathbf{V_R}$.

At about 1508 GMT, the airport changed operations to use runway 24 due to winds, which were reported by air traffic control as 230 at 4 knots and expected to increase.

[8] For this flight, there were test card conditions for rotation at $\mathbf{V_R}$ plus 2, as well as $\mathbf{V_R}$ minus two. It is unclear if FTE-1was indicating $\mathbf{V_R}$ minus two here, or instead indicating rotation should be 2 knots less than what they had been doing for Cards 3A thru 3C. He had previously indicated that he wanted to reduce the $\mathbf{V_R}$ that they had been using ($\mathbf{V_R}$ plus four) by two knots, which would be $\mathbf{V_R}$ plus two.

P-2 asked if the speeds needed to be changed for the next run. FTE-1 replied "…we were gonna try $\mathbf{V_R}$ plus two, so one thirty two for $\mathbf{V_R}$." He added that $\mathbf{V_1}$ would be 125 knots, $\mathbf{V_2}$ would be 136 knots. P-2 set the speeds in the right SMC, and said that he entered a $\mathbf{V_R}$ as 130 knots.

FTE-1 said the next run would be card 3E.[9]

At about 1513 GMT, FTE-1 asked P-3 if he was going to "pull it in but then not keep it in as long, and relax." P-3 said yes, and "once the rate starts I'll just start trying to capture the 9 degrees. But, if I get to the speed, as I'm reducing that" he paused and FTE-1 said "yeah, well, hopefully you want to get to the pitch and then look for the speed."

At about 1515 GMT, P-3 practiced 3 column pulls, and then taxied onto runway 24 for takeoff.

(Card 3E – Speed variation, stick force [*value missing on copy of test card*], VR+2)
[1517 GMT]

Winds: (not verbalized)
Selected $\mathbf{V_1}$: 125 knots
Selected $\mathbf{V_R}$: 130 knots (test card calls for rotation at $\mathbf{V_R}$+2)
Selected $\mathbf{V_2}$: 136 knots
Selected $\mathbf{V_{REF}}$: 147 knots
Weight: (not verbalized)
Selected EPR: (MTO, then 1.20 at $\mathbf{V_1}$ – 20)

P-3 practiced 2 column pulls before the takeoff roll. FTE-1 confirmed that they should rotate at 132 knots for this run. During the maneuver P-3 pitched to about 10 degrees and then maintained an attitude within 1 degree of the PLI. About 8 seconds after rotation, the airspeed indicator flickered from black to yellow.

After the maneuver during the climbout, P-3 said "that one wasn't too bad" and FTE-1 agreed. P-3 added that "it went real well."

After landing, FTE-1 reported that the column force was 72 pounds and the initial pitch rate was 8 degrees per second, with a "better capture." The time between rotation and liftoff was 3.5 seconds and "a lot shorter" time to 35 feet above ground level. They had a 2 knot speed jump right before they rotated, then it went away. He added that the airspeed jumped 2 knots to almost 3 knots and they rotated at 137 knots, and then reduced speed to 134 knots. P-3 said that he thought they were encountering winds because he had to pull up to 14-15 degrees to hold that speed and bring the pitch back down to 11 or 12 degrees.

FTE-1 said to repeat that run one more time and "it looks like probably that will work." FTE-1 said "… as far as the pitch technique, it looked good, I mean you had a lot less, you know." P-3 interrupted with "I just slowly went into it, by the time I'm trying to capture 9 (degrees), I'm at

[9] Card 3E indicates the rotation should be at $\mathbf{V_R}$ plus 2.

my speed and I just keep pulling." FTE-1 said there was a little reduction in pitch, it peaked about 9 degrees and then got down to about 8.5 degrees "and then you pulled back into it."

P-3 asked FTE-1 what he wanted to do for the next run. FTE-1 indicated that he wanted to repeat the last run, because the speeds were "bobbling around" on the last run.

At about 1529 GMT, FTE-4 exited the airplane to check the tires, and returned about 2 minutes later.

At about 1533 GMT, FTE-1 asked if they had relaxed the column at $\mathbf{V_2}$+10 on the previous run. P-3 said yes.

P-3 said he was going to try to capture 135 knots and get a force at that point and then capture 145 knots and get a force at that point, before raising the flaps or adding power.

FTE-1 said that the next run would be card 3E1, which is a repeat of card 3E.

(Card 3E1 repeat – Speed variation, stick force [*value missing on copy of test card***], VR+2) [1539 GMT]**

Winds: 230 at 5
Selected $\mathbf{V_1}$: 124 knots
Selected $\mathbf{V_R}$: 129 knots (test card calls for rotation at VR+2)
Selected $\mathbf{V_2}$: 135 knots
Selected $\mathbf{V_{REF}}$: 147 knots
Weight: (not verbalized)
Selected EPR: (MTO, then 1.20 at $\mathbf{V_1}$ – 20)

At about 1537 GMT, the airplane was cleared for takeoff, and taxied to runway 24. P-3 stated "ok same technique as before" and then performed 4 practice pulls prior to taxiing into position.

P-3 performed 2 practice pulls after setting power to the target EPR setting.
About 21 seconds after rotation, P-3 stated "about right there, that should be it", indicating that he captured $\mathbf{V_2}$. About 3 seconds later, the airspeed indicator flickered from black to red. No sound of stick shaker could be discerned. FTE-1 reported that the control column force at that time was about 16-17 lbs. P-3 stated that he was then going to target 145 knots ($\mathbf{V_2}$+10). Upon reaching 145 knots, FTE-1 stated that the force was about 8-10 lbs.

After the test run, they began their return flight to Savannah. P-3 changed his PFD display from the 2/3 format to the synthetic vision format.

FTE-1 reported that the peak column force was 66 lbs and then relaxed to 15 lbs. The initial pitch was and 9.2 degrees, which reduced to 8.7 degrees. FTE-1 said "speedwise, it's bobbling around when you're coming down the runway." P-3 commented that it was windy. FTE-1 said that $\mathbf{V_R}$ was 131.7 knots. FTE-1 asked P-3 "were you nibbling at shaker there?" P-3 replied "a

little bit." FTE-1 then asked "is that why you sped up a little bit?" P-3 said "no." Their conversation was then interrupted by a transmission from Air Traffic Control.

The crew switched the flight control system mode to Normal Mode.

At about 1548 GMT, FTE-1 said that the times they were getting were "a lot better" than the ones they were getting at Roswell. (FTE-1 may be referring to the elapsed time from rotation to liftoff, the time from liftoff to 35 feet AGL, or both).

FLIGHT 132, Performance: Field: Takeoff OEI, Roswell NM March 14, 2011

Notes:
Recording started at 1238 GMT and ended at 1809 GMT.
Left side HUD is down (deployed).
The left PFD was set to 2/3 mode.
The right PFD was set to SV mode.
The yaw damper was deactivated for this flight per the limitations section of the test card cover sheet.
All takeoffs were on runway 3 unless otherwise noted.
Card 3B1 was the second run of the day, during which a wing drop event occurred. That portion of the recording was transcribed verbatim. The transcript begins as the airplane was rolling out on the runway after the previous run.

Crew for this Flight:
P-2 was the Pilot Flying (PF) in the left hand seat.
P-4 was the Pilot Monitoring (PM) the right hand seat; he was also the Pilot-In-Command for this flight.
FTE-1 was the lead Flight Test Engineer.
FTE-4 was the 2nd Flight Test Engineer.
TM1 and **TM3** were in the Telemetry Trailer.

Test Cards:
The Video Group documented the segments of this flight which related to the following test cards:

Card 3: Performance: Field: Takeoff OEI
(selected excerpts from the Test Description section)

- Flaps 20
- Weight: LIGHT
- CG: FWD LIM
- Set L&R PWR: as specified
- At target $\mathbf{V_{EF}}$ ($\mathbf{V_1}$-20), fail RH engine using a throttle chop to IDLE.
- Rotate at $\mathbf{V_R}$ using 70 lb pull until rotation begins, reduce force to gradually capture 9 deg pitch attitude.
- Maintain target pitch attitude until $\mathbf{V_2}$ is achieved.
- Adjust pitch attitude to maintain $\mathbf{V_2}$ to the lesser of gear retraction complete or 400 ft AGL.

Summary of Video/Audio Recording

At about 1310 GMT, prior to taxiing, the crew was discussing the V_{REF} speed specified as 126 knots on the of test card cover sheet for flight 132. FTE-1 said "…I've gotten data from TM-1

since they were messing with the stall speeds, and it looks like the $\mathbf{V_{REF}}$ I have is lower than that, but we'll use the five knots extra, it's good."
FTE-1 stated that using the 126 knot value would be conservative.
At about 1316 GMT, during the Taxi/Before Takeoff Checklist, P-4 said "the HUD combiner…you've got it workin' finally." (The HUD combiner is noted in the Limitations/Restrictions section of the test card cover sheet as "misaligned in pitch – use caution on landing")

At about 1317 GMT, P-2 performed 8 practice column pulls ranging from 65 to 71 lb force (as reported by FTE-1) after which P-4 said: "you got it man."

At about 1319 GMT, P-4 asked the FTEs to confirm that the AOA limits and shaker settings were correct. He asked to confirm that an NAOA of 1.0 equals 0.84 degrees below the stall AOA, and that shaker activation is set to occur at 0.9 NAOA.

At about 1320 GMT, P-2 performed 2 practice pulls. P-4 then demonstrated what he thought was an appropriate column pull (which was slower than the practice pulls just performed by P-2) and said, "if you do this, you're fine." FTE-1 said "shoot for the light side" and commented that 65 pounds of force would be "good" P-4 then demonstrated a more rapid/abrupt column pull and said, "if you do it like this, your accuracy is #. P-2 performed 4 more practice pulls. P-4 demonstrated another pull and held it, then said "it's pretty much of a step input there, if you just pull it like that."

During the pre-takeoff briefing, P-2 said that at 90 knots they would perform a throttle chop, and P-4 would call rotate. P-2 would pull to 70 pounds, target 9 degrees of pitch, and transition to 116 knots until the landing gear was up. P-4 advised P-2 that if at anytime if he did not like something during the run, that he should position the throttle all the way forward and maintain heading using rudder, and then level off visually or by using the HUD, and start a descent rate if they had enough altitude to accelerate. P-4 indicated that P-2 should watch for the stick shaker, and that he (P-4), would try to provide AOA callouts using normalized AOA values, like "85" or "90 percent", if needed. P-2 asked if the "antlers… the PLI" were at 90 percent while P-4 responded by also saying 90 percent. (meaning the PLI denotes 90 percent of the NAOA). P-4 advised that the antlers would disappear below 0.80 NAOA and if they did disappear, then he could pull harder unless he (P-4) said otherwise. FTE-1 said "looks good." P-2 performed another practice pull.

ATC cleared the airplane for takeoff on runway 3, and provided wind information of 330 degrees at 3 knots before takeoff. P-4 read back the takeoff clearance to ATC.

P-4 completed the before takeoff checklist, and re-briefed the maneuver.

P-2 performed 3 more practice pulls.

P-4 announced that the run would be Card 3B.

(Card 3B - L PWR: Med Gradient, R PWR Med Gradient to throttle chop to Idle)
[1325 GMT]

Winds: 330 at 3
Selected $\mathbf{V_1}$: 110 knots
Selected $\mathbf{V_R}$: 112 knots
Selected $\mathbf{V_2}$: 116 knots
Selected $\mathbf{V_{REF}}$: 126 knots
Weight (not verbalized)
Selected EPR: (1.53, then RH to IDLE at $\mathbf{V_1}$ – 20)

During the takeoff roll, P-4 called out 70 knots, then at 80 knots he retarded the right throttle into IDLE position. After P-4 called rotate, he apologized and stated that he did not call rotate at the correct speed, because he was thinking about 116 knots (which was the $\mathbf{V_2}$ speed), and he said that they would repeat the run. He added that he was "not used to doing this thing from over here" (the right seat position).

While returning for landing to the runway, P-2 asked what $\mathbf{V_R}$ was, and P-4 said that it was 112 knots and that it was his (P-4's) "fault" (that he did not call the rotate at the correct speed).

FTE-1 reported the control column input was "good" and that the peak column force was about 64 lbs. He noted that the pitch attitude was 9.6 degrees and it was "a little high."

During the final leg of the approach to the runway, FTE-4 commented "good golly that's squirrelly". P-4 asked, "you mean the yaw damper off?" P-2 said that "it feels a lot looser than it normally does". During this time, the heading was oscillating back and forth as seen on the navigation display.

After landing, P-2 said the airplane was "really loose directionally… a lot more so than we've done since we've been flying without the yaw damper." P-2 asked if the CG was forward and FTE-1 replied "yeah, we're at the forward limit….less fuel and we didn't change any ballast."

FTE-1 reported that the $\mathbf{V_R}$ was 116 knots and the technique was good. P-4 said that he provided a rotate call that was 4 knots too fast. P-2 said that (on previous flight(s)) he had been calling the $\mathbf{V_R}$ callout about 1-2 knots early (to provide a lead-in such that the actual rotation would occur at $\mathbf{V_R}$.).

(CARD 3B1 – repeat of 3B – L PWR Med Gradient, R PWR MTO to throttle chop to IDLE) [1333 GMT]

Winds: 300 at 5
Selected $\mathbf{V_1}$: 110 knots
Selected $\mathbf{V_R}$: 112 knots
Selected $\mathbf{V_2}$: 116 knots
Selected $\mathbf{V_{REF}}$: 126 knots
Weight (not verbalized)
Selected EPR: (1.53, then RH to IDLE at $\mathbf{V_1}$ – 20)

(Transcribed section begins as the crew are discussing the previous (card 3B) and upcoming (card 3B1) runs).

(Beginning of transcribed section)

Time	Source	Comment
13:30:08	P-4	kinda the same thing, we're gonna rotate like, way different….. four knots.
13:30:20	P-2	I kinda had the one sixteen planted in my head.
13:30:22	P-4	should have the speeds on your HUD.
13:30:24	P-2	oh yea no no I was watchin… well I had the one, yeah.
13:30:29	FTE-1	you can shoot for one sixteen but I mean – just if we're gonna blast right through it with this acceleration, we'll get what we get.
13:30:36	P-2	yeah yer sayin.
13:30:37	P-4	were gonna go to we'll do it at one twelve.
13:30:38	P-2	*.
13:30:39	FTE-1	yeah rotate at one twelve, but we'll see whatever $\mathbf{V_2}$ falls out, so.
13:30:43	P-2	he's sayin were probably not gonna be able to hold the pitch enough to slow it with the thrust.
13:30:45	P-4	eh you'll be able to do it. * the mishap pilot was heard to say. ok. so. uh, gonna do the same thing.
13:30:52	P-2	same numbers.
13:30:54	P-4	I'll pull it to idle at one ten, er at ninety knots, $\mathbf{V_1}$ will be one ten, I'll call it, then I'll call rotate, just prior to a hundred and twelve.
13:31:02	P-2	ok.
13:31:03	P-4	and uh and then you just rotate to nine degrees intercept one sixteen, not to exceed point nine alpha. maintain- do it just like you did last time. just- you won't be able to tell it any different from the last run.
13:31:15	P-2	three two one pull. (P-2 practiced the control column input)
13:31:17	FTE-1	that was sixty six, that's good. (referring to the column force in pounds)
13:31:20	P-2	three two one pull.
13:31:24	P-2	three two.
13:31:26	FTE-1	that was sixty seven, those are good.
13:31:31	P-2	all right. lets do it.
13:31:32	P-4	all righty ok we got-

Time	Source	Comment
13:31:34	RDO-P-2	uh Gulfstream test five two's ready for takeoff, three.
13:31:39	TWR	Gulfstream test five two Roswell tower runway three clear for takeoff, winds three zero zero at five, teardrop is approved, uh, just report base.
13:31:48	RDO-P-2	wilco, cleared for takeoff and teardrop.
13:31:50	P-4	'kay exterior lights, we've got them set. the transponder is still transponding, the ground spoilers are coming to the ARMED position again, radar is off, V- speeds we've got em set, we've talked about it, rotate at one twelve, climbout at one sixteen, the EICAS is uh, got the same players. 'cept for the autopilot which - no, it's still there, uh departure runway alignment, and the nosewheel steering power will remain on.
13:32:18	FTE-1	that all checks. EPR's one five three.
13:32:23	P-2	five three, still set.
13:32:27	P-2	everybody ready?
13:32:28	FTE-1	ready in the back.
13:32:29	P-2	TM ready?
13:32:33	P-2	(TM-3) can you hear me? TM ready?
13:32:37	TM	TM here.
13:32:37	P-2	all righty.
13:32:39	P-2	all right, powers comin up, one five three.
13:32:51	P-2	fifty three set, three, three two one, release.
13:32:55	P-4	there you go, looking good. ok one fifty three on the engines…. off the peg.
13:33:04	P-2	ok. (P-4 was following on the control column with his left hand, his right hand was not visible)
13:33:04	VID	(P-2 moved his right hand from the throttles to the control column, (both hands on column, P-4 moved his left hand from the column to the RH throttle).
13:33:04	P-4	I've got the right engine… ok there's ninety knots, the engine's comin' to idle.
13:33:13	VID	(P-2 pulled back on the control column).
13:33:13	P-4	uh- ok.
13:33:15	VID	(P-2 reduced the control column input (forward), and input left wheel)
13:33:15	P-4	whoa whoa (P-4 put hands on control column and pushed abruptly forward).
13:33:17	FTE-1	whoa whoa.
13:13:17	VID	(P-2 initially reduced the control column input, (forward) and then increased it slightly (back) and reduced the wheel input toward neutral).
13:33:17	P-2	I got it, got it got it got it.
13:33:19	VID	(P-4 moved left hand from control column to the RH throttle and pushed it forward, then both pilots push both the throttle levers forward to the forward limit of the throttle quadrant).
13:33:21	P-4	way high, and way early.
13:33:25	P-2	I saw it hit the $\mathbf{V_1}$ on there, no? I didn't hear the rotate but I saw the $\mathbf{V_1}$.
13:33:29	P-4	I was just about to say rotate.
13:33:31	P-2	but I over rotate- I over rotated.
13:33:32	P-4	rotated about a hundred and nine. something like that.

Time	Source	Comment
13:33:35	P-2	get this slowed to-
13:33:37	FTE-1	that about eleven degrees on the pitch there.
13:33:40	?	yeah.
13:33:41	FTE-1	you oughtta, shoot low for that.
13:33:43	P-4	what was the rotate speed?
13:33:45	FTE-1	uh, standby.
13:33:47	FTE-4	one ten. no sorry, one twelve. (there was some confusion during Video Group about this response being for the planned $\mathbf{V_R}$, or the actual $\mathbf{V_R}$)
13:33:53	P-4	I was lookin at - * * have you V- have you got this- I was lookin at- when you did that, I was getting ready to call rotate-
13:33:58	P-2	I saw the needle hit the $\mathbf{V_1}$, so I just went ahead and pulled * (the HUD has a round airspeed dial display which has "needle" indicator)
13:34:01	P-4	ok. too much, you're doin' that too much.
13:34:04	FTE-1	yup.
13:34:13	P-4	what was the uh, pitch angle?
13:34:15	P-2	eleven he said.
13:34:18	FTE-1	peak was uh-
13:34:19	TM	TM sees twelve.
13:34:20	FTE-1	twelve… point one, yeah…. it was bouncing around when I was tryin' to look at it.
13:34:26	P-2	all right.
13:34:27	P-4	okay, flaps are twenty gear is down.
13:34:31	FTE-1	peak pitch was sixty six err, force.
13:34:34	P-4	and what speed did you see the rotate at?
13:34:36	FTE-1	one ten is what I'm seein'.
13:34:38	P-4	yeah that's what I was lookin' at too. I saw one oh nine actually on my indicator when it came back-
13:34:47	P-2	all right we'll I'm just gonna wait for the rotate then, I won't uh-
13:34:50	FTE-1	I think we – the other thing is, is we've changed the trim a little bit so you're getting a litt- with seventy pounds of pull you're getting more for- more elevator.
13:35:00	P-2	* say that one – we had the same trim setting as the first time?
13:35:03	FTE-1	yeah.
13:35:03	P-4	ok lets – lemme give lemme give you the you the-
13:35:07	P-2	ok the flaps twenty.
13:35:08	FTE-1	-check the trim for yah.
13:35:08	TWR	Gulf test five two runway two one, cleared to land, winds three one zero at six.
13:35:11	RDO-2	runway two one, cleared to land.
13:35:19	P-4	ok the gear indicates down, the flaps to full, the spoilers are armed, check your nosewheel steering on.
13:35:23	FTE-1	I think we had the stab set wrong
13:35:25	P-4	yeah.

13:35:27	P-2	ah ok I was gonna say, because it came up a lot faster than it did the first time we did it.

Time	Source	Comment
13:35:30	P-4	yeah you're probably right.
13:35:33	P-2	what's the stab, what's the stab setting * ?
13:35:37	P-4	five point.
13:35:37	FTE-1	five point six is what we should have.
13:35:38	P-2	can you go back and look at it, and see what it was?
13:35:40	P-4	it was higher.
13:35:42	FTE-1	it was six point-
13:35:43	P-2	ok.
13:35:44	P-4	eh it wouldn't make much difference, I don't think.
13:35:46	P-2	eh it- it- it, it jumped. what was the pound pull?
13:35:49	FTE-1	seventy…sixty-
13:35:52	P-4	you held it a long time-
13:35:53	FTE-1	sixty five, you held it a little bit, but I think you're- we had the stab set wrong.
13:35:57	P-2	yeah I mean-
13:35:58	P-4	that half a degree-
13:35:59	P-2	that force-
13:36:01	FTE-1	it's ah minus six point two, does that sound right?
13:36:05	P-4	uh, no
13:36:06	FTE-4	should have been five point six.
13:36:07	P-4	yeah…. that's what I was sayin a half a degree-
13:36:10	P-2	but the-
13:36:11	P-4	-doesn't make a # of a lot of difference.
13:36:12	P-2	-but the pound pull was right, right-
13:36:14	FTE-1	yeah.
13:36:15	P-4	-where it was supposed to be, so.
13:36:15		(end of transcribed portion)

Summary of remainder of test run 3B1

After landing, P-4 said that 0.5 degree of trim does not have much of an effect, and advised "you just gotta intercept it, whatever it is." He further advised P-2 to "catch it quicker" and stated that "you're doing a rapid step input, but you gotta, you've got to, intercept the 9 degrees… slow it down if you need to."

FTE-1 stated that they had reached about 8 degrees of roll on that run. P-2 stated that he was trying to be "gentle with it as it started to go", because "directionally without the yaw damper its' really uh" (P-2 makes a side to side shaking gesture with his hand).

P-4 advised P-2 that the maneuver had been performed too aggressively. P-2 stated that the 65 pounds of pull on the column was the same (as previously done) but with the improper trim setting, the pitch rate "came a lot faster." FTE-1 stated "you did what you were supposed to, it's

just it's too much." P-2 said that he would do it slower, (apply the input to the control column slower) and P-4 reiterated that it had to be done slower.

P-4 demonstrated an aggressive pull on the control column and stated "you take that thing and holding it, to me it's too aggressive, and you are pulling it up into a stall." FTE-1 agreed.

P-2 practiced pulling back on the control column 4 four times at a slower rate. P-4 decided the next run would be an all engine operating takeoff with an EPR setting of 1.45, and he advised P-2 to "just pull it up to nine degrees….it doesn't have to be real fast….and you'll get a feel for it." He added "…we can't do that again, we can't have that… we can't pull it into a stall."
P-2 "totally agreed." He said "I think we messed with the trim, which induced a different thing."

P-4 stated that the trim was half a degree off, and that can change "it" a little but won't change it very much. He explained that he had experienced 1 degree differences in trim before and "it's like the CG is further aft." He showed P-2 the center of gravity envelope attached to the test cards and discussed it. He further explained that there is "a little less inertia, but the inertia is in the wings, but none of that matters you just have to accept the rate and you know if you get it mistrimmed a half a degree you can't crash the airplane. You've got to - got to stop the rate at 9 degrees."

P-4 suggested that part of the problem may have been the use of HUD due to its expanded scale. He explained that he preferred to use the PFD (in its 2/3 display format) because there is "too much happening" on the HUD. He stated that he had been using HUDs for a long time and felt that it was better to use the HUD "once you get going." P-2 agreed, and decided that he would use the PFD as his reference instead of the HUD. P-4 pointed P-2's PFD (which had already been configured to the 2/3 format display) and said "you can see it coming there, and see it over-shoot."

P-4 briefed the next run, and said they would do a moderate rate pull up to 9 degrees with both engines operating. He explained that this would allow P-2 to get a little confidence to do the maneuver, and that it would be difficult to do without having confidence. P-4 asked FTE-1 if this was acceptable and FTE-1 agreed.

The crew decided to use an EPR of 1.45, which was the lowest climb gradient they had.

P-4 confirmed that the speeds would remain the same and that the trim setting would be 5.6, and P-2 performed 2 practice pulls on the column.

While taxiing into position, P-4 commented that they should perform a "nice and smooth but rapid rotation." FTE-1 added "smooth, and don't overshoot 9. Shoot low."
FTE-1 decided to call this run Card 2C (later revised to Card 2A).

(CARD 2A L&R PWR 1.45 Low Gradient)
[1344 GMT]

Winds: 320 at 5 (provided by tower)
Selected $\mathbf{V_1}$: 110 knots
Selected $\mathbf{V_R}$: 112 knots
Selected $\mathbf{V_2}$: 116 knots
Selected $\mathbf{V_{REF}}$: 126 knots
Weight: (not verbalized)
Selected EPR: 1.45

During the takeoff roll, FTE-1 advised the crew to not exceed 20 degrees of pitch on the climbout. Shortly after rotation, P-2 said that the he would have to pull way back to capture $\mathbf{V_2}$ (which he did not). FTE-1 said that the run was "good." P-2 asked if he had rotated late. P-4 responded that said he called $\mathbf{V_R}$ at 112 knots, and added that calling it at 112 knots might be late. FTE-1 said that the speed "jumped up like 110 and then went to 117 back down."

At 1346 GMT, FTE-4 asked to review the test cards because she wanted to make sure that TM knew what they were doing and how they were labeling the cards. She said that Card 2A was low gradient, 2B was medium gradient, and 2C was maximum takeoff power. FTE-4 stated that she was not sure what they were doing. P-4 responded that they were just doing some "build-up tests, to get the rates down." FTE-4 and FTE-1 concluded that the run just performed should be labeled as Card 2A.

After the landing rollout, P-4 said "see, you're pulling, to me…" (he then performed an example pull on the column) "Like that." P-2 inquired/stated "still too fast." P-4 then said "I mean I would just pull it" (he then performed another example pull on the column, slower than the first one) "Like that."

At about 1349 GMT, P-4 asked what the pitch was on the run. TM responded that it was 9.6 degrees, and P-4 noted that was "pretty good". FTE-1 added that peak column force was 54 lb, and the rotation speed was about 117 knots, but it was "bouncing around" at the time and difficult to pinpoint.

FTE-1 asked if the pilots wanted to perform another all engine takeoff, P-4 responded that he wanted to perform a single-engine takeoff, and advised P-2 to "just slow your rate down… a slow rate to 9 degrees… don't worry about getting the data, just slow it down and intercept 9 degrees." FTE-1 added "that should be your main focus, I'd worry less about the rate."

As the crew discussed the steps for the next takeoff, P-4 said "…and we'll pull the right engine back and then you'll rotate, you know on the rotate, just rotate it, you know, like you rotate an airplane….you can rotate it smartly, (he then performed an example pull on the column) but try to intercept it."

P-2 performed 12 practice pulls on the control column (without the force values being called out). P-4 performed a practice pull and asked what the pull force was, while

P-2 followed along on the on the controls (hands on the yoke at the same time).
FTE-1 replied that it was 62 pounds. P-4 performed several practice pulls to demonstrate and discuss what he believed to be the appropriate rate and extent (how far to pull) for the column input. P-4 explained "as soon as you pull that rate, then you're looking at that nose to intercept the ten (degrees of pitch) and just fly that ten." He further stated "and its gonna be back to neutral pretty much, once you get there." FTE-1 added "…don't hold it in, just take it back out as soon as you get the nose comin up." P-2 then performed 3 practice pulls.

The crew then waited on the ramp for other traffic to clear. During this time, P-2 performed 7 practice pulls.

At about 1356 GMT, P-4 said that the runs they were performing were not for the purpose of collecting data, but rather to "get the technique down."

FTE-1 said that he was "expecting that… you're gonna end up high on $\mathbf{V_2}$" which he said was ok for the light airplane weight. P-4 added that with a rotation speed of 111 knots, with power on, by the time the nose rose up the speed would already be faster than the $\mathbf{V_2}$ of 115 knots. He further stated that it was "impossible to maintain it to not go overshoot it."

At about 1359 GMT, P-4 briefed the next takeoff and P-2 performed 3 practice pulls. P-4 said to rotate to 9 degrees and try to intercept the $\mathbf{V_2}$ of 115 knots, "unless you're in (stick) shaker." FTE-1 asked the pilots if the stick shaker activated on the previous run which had the roll off event. P-4 said he didn't think it activated, but he did not have his hands on the controls at the time. P-2 said that it did not activate, and FTE-1 appeared surprised that it had not. P-2 said that the "PLI came up on top" but there was no stick shaker.

P-4 asked "what was the wing drop, about eight degrees (of roll attitude)?" FTE-1 replied "Yes. I've done two of those (wing drops), that's enough."

P-2 performed two practice pulls.

At about 1403 GMT, TM-4 in the TM trailer asked which test card was next, and FTE-4 replied that it would be Card 3B2. P-2 performed 4 practice pulls.

FTE-1 asked "what (reference) are you looking at to capture the pitch?" P-4 responded that P-2 was using the HUD display, and commented that the HUD had a very expanded scale. He added that using the HUD was a good way of doing it, but the problem with that was that "you translate through a lot of space so it gets a little bit, to me, it gets a little disorienting when you are doing rapid pitch changes like that and you want to do accurate captures because you don't really see it coming." P-2 stated that "you can't see it when you are sitting level, because its off the top." (apparently referring to the pitch attitude graduation for 10 degrees being not visible at a level attitude because the scale is so large that the reference is off the top of the HUD display).

P-2 said that the initial pull on the run they had just completed was not much different than the pull on the run where the wing had dropped. He asked FTE-1 how long the initial column input was held in, during the run with the wing drop. P-4 stated that "you've got to intercept it, what-

ever you're rate is." P-2 said, "you gotta pretty much release it as soon as you get to it." P-4 said, "before you get to it." P-2 said, "no no no, the pound set, (he motioned the control column pull with his hands) you gotta start releasing off of it, to capture the nine (degrees of pitch)."

P-4 said, " I think you're just being too aggressive with it… it's got a short period its gonna work through… once you pull on this (he demonstrated a pull on the column) then its gonna start moving (he demonstrated the airplane pitching upwards with his hand) and its gonna keep accelerating, and as it accelerates, then when you stop (he demonstrated a push on the control column) it's gonna have a short period bobble, and its gonna bobble up like into a stall, and then down. So what you have to do is catch it before it gets to nine degrees (he demonstrated another push on the control column) and then intercept it."

FTE-1 said that on the run with the wing drop, the column input force was 58 lbs with a step input, and then held in for about 1.8 seconds. P-4 asked what the pitch attitude was, at the time that the column force began to reduce. FTE-1 said that it was almost 10 degrees and that "he was kind of holding it in" (the column force).

P-4 said "see you held it in until you were overshooting it, and then the airplane is going to operate through the short period. You need to be reducing it like you know, at 5 degrees (of pitch) or something."

P-2 said that he thought that it was due to trying to use the HUD. He indicated that using the PFD instead (in 2/3 display mode) would be better because "you can see the whole rate the entire time."

FTE-1 said "I think…as soon as you get there and the nose starts moving, take it out (the column input) and then you will be able to control it better to capture it." He added that during the run with the wing drop, the peak rate was about 8 degrees per second, and that (the 8 degrees/second pitch rate), occurred "right at 10" degrees of pitch.

P-4 advised to slow the rate down to something manageable. FTE-1 said "you were rocketing up there." P-4 said "we could do these all day, at less pitch, it's no big deal, so you know undershoot it, it's no big deal."

FTE-1 said "yeah you could shoot for eight, and if we get eight and a half, that's (unintelligible)." P-4 said, " shoot for seven, shoot for five….I've spent a lot of time in the middle of the night thinking about how I was going to get this done, and I said, well, you know, it's a short period, you gotta (unintelligible) you gotta get it moving, so you gotta do this (he pulled back on the column) and that (he released/pushed on the column) so I'm doin' – I just did it slower. Just doin' a slower input, and its more controlled. Some of the ones we were doing we were fortunate you know getting the feel of it (demonstrated another pull/release on the column), I had gotten the opportunity to do a few but, (demonstrated another pull/release) I just had to slow it down." FTE-1 said "the peak normalized we got when that was happening was around 86 percent… we're putting it at ninety, and I mean that wouldn't have gave you any help you know."

P-4 replied “well there’s nothing you could do at that point anyway, because it’s in the short period.”

At about 1407 GMT, P-4 briefed Card 3B2 for the next takeoff with a rotation to 9 degrees. He advised to do a control column input “just like that” as he demonstrated a column pull. “You don’t have to do ah” (he demonstrated a more aggressive faster pull on the column). P-2 said that that he had been looking at P-3’s control input technique all week “at that rate” and “kinda got that into my head.” P-4 said “well, get it out.” P-2 agreed, and said that he realized that he needed to slow it down, he just had to “deprogram” himself, but he understood and was working on it.

(CARD 3B2 L&R PWR 1.53 Med Gradient)
[1409 GMT]

Winds: 347 at 6 (provided by FTE-1)
Selected $\mathbf{V_1}$: 109 knots
Selected $\mathbf{V_R}$: 111 knots
Selected $\mathbf{V_2}$: 115 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: 67,000 lbs
Selected EPR: 1.53

During the takeoff roll, the airspeed indicator appeared to pause at 90 knots and then increase (jump) to about 110 knots. During the initial climb, P-4 said “easy on the rate, easy on the rate.”

After the maneuver, P-4 said that the takeoff was good, I was just a “little touchy on the rate.” P-2 said that he could see the PLI and that the pitch attitude was about 3 degrees below it.

FTE-1 reported that the $\mathbf{V_R}$ speed was 110.8 knots, the captured pitch was 9.4 degrees, the column force was 65.8 pounds, and that the run was good. P-4 advised P-2 to not be any more aggressive than that. FTE-1 agreed. FTE-1 reported that the initial column input was held in for about 1 second, and that P-2 could try even less duration than that. The peak pitch rate was about 6.5 degrees/sec, which FTE-1 said was “still pretty sporty.”

At about 1412 GMT, TM-3 reported that TM-1 said that the right engine was windmilling (the right engine speed was not at idle) when they were rotating on Card 3B2.

P-2 asked if there would be performance tests with more aft center of gravity (CG). FTE-1 said no, and P-4 explained that for performance testing the forward CG is used because it’s the worst case. He said that testing could be done at aft CG but “you have to contain the rate.” FTE-4 asked why the forward CG is the worst case and P-4 explained that forward CG could conceivably require more runway because there may be a condition in which the airplane may not rotate as quickly or as easily. P-4 said “...you could not get the airplane nose up early enough or fast enough to get off the runway.”

At about 1416 GMT, FTE-1 said that he wanted to look at the data, "as far as directional." He said that that there were about 17 degrees rudder "at about rotate." The engine pull back was a little bit late, which P-4 indicated was "a little bit intentional."

There were about 25 degrees of spoiler input at liftoff. TM-3 said that she had seen similar inputs on a couple runs, but this one was the highest.

FTE-1 said the airplane rolled about 3 - 3.5 degrees during the liftoff and it was felt in the back of the airplane and they could see that the wings were not level. He noted that was contrary to testing on the previous day where it had been a non-event when the airplane rotated and lifted off.

P-4 suggested that they discontinue the takeoff performance tests and go back to take a look at the data from the runs they just performed. FTE-1 agreed and said that he wouldn't mind spending some time to look at the data and "this seems like we're on the edge of what the airplane's" (comment interrupted). P-4 and FTE-1 decide to perform landing performance and rejected takeoff (RTO) testing until the takeoff data could be reviewed.

At about 1429 GMT, prior to the first RTO test, FTE-1 stated that on takeoff, they had been getting 3 degrees of roll and 3 degrees or so of sideslip.

The crew performed two test runs consisting of an RTO test run followed by a takeoff, to cool the brakes.

At about 1503 GMT, while the airplane was airborne for brake cooling purposes, P-2 left his crew seat to use the lavatory. P-4 said that they would "finish up these things and go back." FTE-1 said "I want to look at it and talk back to Savannah a little bit" (with regard to the data from the performance takeoff runs). He added "the thing is, this has got to be something I can have- the FAA can do, it can't be this hard a technique you know (the takeoff technique). If I can't train you guys to do it then-" (comment interrupted).

P-4 said that he would do the remainder of these tests (takeoff performance tests) because P-2 "doesn't have much experience in Gulfstream airplanes… and it is a little bit of a wild maneuver, in case you haven't noticed." FTE-1 responded "yeah it was a little wild there, kinda got shook." He added he was going to have to get (the FAA certification official) to come out to do these tests and he thought that (the FAA certification official) had more experience doing these tests. FTE-1 thought that the takeoff technique needed to be more like "pull it in and take it right back out and then look for the pitch attitude." P-4 agreed and said "theres are a lot of technique but you get wrapped up in the moment." FTE-1 said that he understood and noted that "everybody is trying hard to get the best data." P-4 said he would let P-2 "get him practice doing the braking and all that other stuff" and by then P-2 would have more experience in the airplane. He agreed with FTE-1 about the FAA (Atlanta Aircraft Certification Pilots) and said "a couple of the guys there are a little bit shaky…they don't get to fly much." P-4 added that "it's really unfair to have them come (unintelligible) expect them to do this stuff, when they don't fly the airplane. Most of the problems we've had in the cert (certification) have been with the FAA flyin'."

At about 1505 GMT, P-2 returned to his crew seat. About 10 minutes later the airplane landed and taxied to maintenance for a brake check.

At about 1520 GMT, while reviewing the speeds for the next RTO test run, ($\mathbf{V_1}$-108 knots, $\mathbf{V_R}$-110 knots, $\mathbf{V_2}$-121 knots), P-4 commented that it did not seem to make sense that the spread between $\mathbf{V_R}$ and $\mathbf{V_2}$ was four knots when using flaps 20, yet 11 knots when using flaps 10. He discussed this with FTE-1, who said they "bumped" up the speed 2 knots yesterday. He said $\mathbf{V_R}$ should be 112 knots for the upcoming run.
P-4 then left the crew seat for a lavatory break.

At about 1523 GMT, P-4 returned to the right crew seat. He asked why 10 degrees of flaps makes such a difference in V-speeds and said that it seemed to him that "if you can do that at ten degrees, that you ought to be able to rotate slower at twenty degrees." FTE-1 said that the $\mathbf{V_R}$ is being limited by the $\mathbf{V_{MC}}$. He said "When we're at the $\mathbf{V_{MC}}$ weight so you can't go any slower where with either one we use the same speed for both." He further stated it is "mainly how much acceleration you're gonna get during the rotation to thirty five (feet AGL)." FTE-1 said "so I guess we're thinking the drag is so much you know, less, that you're gonna get more acceleration for the same rotate speed…yesterday, when we did that medium weight (takeoff) with the flaps ten it was like we were at the pitch attitude and pretty much waiting to lift off for too long and we're at a $\mathbf{V_{MU}}$ attitude so that's why we pushed that one forward for flaps 10."

At about 1554 GMT, after completion of an RTO test followed by a maximum power takeoff, (runway 3 with flaps 10 degrees), FTE-1 reported that the takeoff's pitch attitude was 9 degrees and the peak pitch was 9.8 degrees and went back down to 8 degrees. The initial column force was 40 pounds which increased to 50 pounds when P-2 was not getting the pitch he wanted. FTE-1 added that P-2 still had a pitch rate of 8 degrees per second and it "was coming up." P-2 asked FTE-1 what pitch rate was preferred, FTE-1 said "well, the faster the pitch rate and if you can capture the pitch attitude without overshooting too much, (P-3) was getting around 8 (degrees per second) and that was getting quick times."

FTE-1 said we are looking for an average rate from the time of the initial column input until liftoff, of about 3 degrees per second. He further stated that it should be about 2.5 or 3 seconds from the initial pull until the target pitch attitude would be achieved. P-2 said "set the pull and release it right away and anticipate to stop it." FTE-1 said that "you have to pull hard…not hard… but pull smartly, and then slow the pitch rate down right away and then capture." FTE-1 said "don't hold it in, just take it back and capture the attitude, 'cause as soon as you pull it's coming up (the pitch attitude)."

At about 1602 GMT, while airborne to cool the brakes, P-2 asked "and y'all need to look at the data before we do anymore of the takeoff stuff." FTE-1 said yes, he wanted to "talk to them back there, if they are going to be able to get us the yaw damper and stuff and then just look at the speeds a little more and the stick forces."

At about 1609 GMT, TM-3 asked FTE-1 if he would need TM (apparently with regard to the next test or tests) and he replied that he did not, saying "we are not doing anything that (TM-1)

wants to look at, I don't think….it's a parking brake stop from a landing, some taxis, and a single hydraulic landing."

At about 1727 GMT, while flying during a brake cooling run, the crew reviewed the parameters from the previous takeoff. P-4 was seated in the left seat for this flight,
P-2 was in the right seat. FTE-1 reported that the initial column force was 65 lbs, the peak pitch rate was 6.6 degrees/sec and the pitch angle was "exactly" 10 degrees. FTE-1 commented that would be a "good takeoff technique." P-4 said, "I'm gettin that down I can figure it out…and you know what it is? it's really like mild." FTE-1 inquired "like what?" P-4 said "it's mild, it's not like a big jam (he motions a rapid pull with his hands) I'm just kinda rotating, but a little bit smartly." FTE-1 stated "smartly rotate."

The conditions for this previous takeoff were:

Runway 21
Flaps (unknown)
Winds: 150 at 7
Selected $\mathbf{V_1}$: 110 knots
Selected $\mathbf{V_R}$: 112 knots
Selected $\mathbf{V_2}$: 116 knots
Selected $\mathbf{V_{REF}}$: 122 knots
Selected EPR: (appeared to be MTO).
(P-4 said that they could use the "same speeds", which were last set at 1632 GMT a few runs earlier for a flaps 20 takeoff at 68,300 lbs.)

FLIGHT 153 Performance: Field: Takeoff – Roswell, NM April 2, 2011

Notes:
All times specified for this flight are noted in local time (Mountain Daylight Time) which is GMT – 6 hours.[1]
Recording started at 0630 MDT and ended at about 0934 MDT.
All takeoffs are on runway 21 unless otherwise noted.
The accident occurred during run Card 7A2.

Crew for this Flight:
P-1 was the Pilot In Command in the left hand seat.
P-2 was the Second In Command in the right hand seat.
FTE-1 was the lead Flight Test Engineer.
FTE-2 was the 2nd Flight Test Engineer.
TM-1, TM-3 were in the telemetry trailer. (additional personnel were present in the TM trailer during this flight, however their voices are not heard on the recording. See the Operations Group Chairman Report for more information.

Test Cards:
The Video Group documented the segments of this flight which related to the following test cards:

Card 2: Performance: Field: Takeoff AEO
(selected excerpts from the Test Description section)

- Flaps 20
- Weight: MTOW
- CG: FWD LIM
- Set L&R PWR: as specified
- Rotate at $\mathbf{V_R}$ using 65 lbs pull until rotation begins, reduce force to gradually capture 9 degrees pitch attitude
- Maintain target pitch attitude until Rate-of-Climb $\mathbf{V_2}$+10 is achieved, then transition to speed. Do not exceed 20 degrees pitch attitude.
- Adjust pitch attitude to maintain $\mathbf{V_2}$+10 to the lesser of gear retraction complete or 400 AGL.

[1] Times expressed as HHMM (hours and minutes) are approximate. Times expressed as HHMM:SS.XX (hours, minutes, seconds, and decimal seconds, if applicable) are provided as precise timing references for synchronization with other recorded data sources (e.g Cockpit Voice Recorder).

Card 3: Performance: Field: Takeoff OEI
(selected excerpts from the Test Description section)

- Flaps 20
- Weight: MTOW
- CG: FWD LIM
- Set L&R PWR: as specified.
- At Target $\mathbf{V_{EF}}$ ($\mathbf{V_1}$ -20) fail RH engine using a throttle chop to IDLE.
- Rotate at $\mathbf{V_R}$ using ___lb pull until rotation begins, reduce force to gradually capture 9 degree pitch attitude.
- Maintain target pitch attitude until $\mathbf{V_2}$ is achieved, then transition to speed.
- Adjust pitch attitude to maintain $\mathbf{V_2}$ to the lesser of gear retraction or 400 ft AGL.

Card 6: Performance: Field: Takeoff AEO
(selected excerpts from the Test Description section)

- Flaps 10
- Weight: MTOW
- CG: FWD LIM
- Set L&R PWR: as specified
- Rotate at $\mathbf{V_R}$ using ___lbs pull until rotation begins, reduce force to gradually capture 10 degrees pitch attitude.
- Maintain target pitch attitude until Rate-of-Climb $\mathbf{V_2}$+10 is achieved, then transition to speed. Do not exceed 20 degrees pitch attitude.
- Adjust pitch attitude to maintain $\mathbf{V_2}$+10 to the lesser of gear retraction complete or 400 AGL.

Card 7: Performance: Field: Takeoff OEI
(selected excerpts from the Test Description section)

- Flaps 10
- Weight: MTOW
- CG: FWD LIM
- Set L&R PWR: as specified.
- At Target $\mathbf{V_{EF}}$, fail RH engine using a throttle to IDLE.
- Rotate at $\mathbf{V_R}$+2 using ___lb pull until rotation begins, reduce force to gradually capture 10 degree pitch attitude.
- Maintain target pitch attitude until $\mathbf{V_2}$ is achieved, then transition to speed.
- Adjust pitch attitude to maintain $\mathbf{V_2}$ to the lesser of gear retraction or 400 ft AGL.

At about 0642 MDT, P-2 climbed into the right-hand seat in the cockpit. About 3 minutes later, P-1 climbed into the left-hand seat in the cockpit. P-1 asked if the FTEs are "up in the back" and (unknown) replied "yes." P-1 was holding the test card cover sheet on his lap, with various portions highlighted. P1 performed a practice pull on the column. P-1 and P-2 began the before starting engine checklist. At about 0656 MDT, FTE-1 was troubleshooting flight control error messages which indicated that some flight control actuators had not activated. P-1 said that FTE-1 may have to call (another FTE), however FTE-1 spoke with FTE-3 on the phone instead. The flight control error messages were cleared and the crew performed flight control checks.

At about 0705 MDT, P-1 said that runway 21 was good because they wouldn't be flying over people's houses. The crew began the taxi. FTE-1 said that he had talked to FTE-3 about the yaw damper and FTE-3 said that there was no need to monitor it. P-1 said that (another FTE) had been monitoring it to make sure the yaw damper "washes out" before a rolling takeoff. FTE-1 offered to monitor it, and P-1 said "yeah, we'll see how it is."

P-1 said "we are all set up here, with uh - we got a 9 degree line up here…"(he had programmed the flight path angle (FPA) mode to cause a 9 degree pitch reference line to appear on the primary flight display). He said that he had practiced his pull forces and would do it now one more time as they were taxiing to the runway. He practiced pulling on the column two times, said he was targeting 60-65 pounds, and "that's kind of what I'm going to shoot for. That's what I used the other day and it seemed to be bobble-free."

P-1 performed four more practice pulls, and P-2 said that he had selected air data system 1 to match P-1's air data system. FTE-2 asked FTE-1 where to find CG on the performance screen, and FTE-1 said it was on the secondary field performance screen.

At about 0708 MDT, P-1 briefed the takeoff. P-2 began reading before taxi/before takeoff checklist and confirmed that the flight controls were in first flight mode. P-1 said that he was caging the HUD (and he selected "caged" on the SMC). P-1 confirmed with TM-3 that the wind station was operational.

At about 0710 MDT, TM-3 announced they would be starting with card 2C1. P-1 looked at card 2, which appeared to have the areas specifying a 9 degree target pitch and "do not exceed 20 degrees pitch" highlighted. P-2 briefed card 2, all engine takeoff. He confirmed the target speed of $\mathbf{V_2}$+10 speed with FTE-1. FTE-1 asked the pilots to "hold short here for a minute while I get configured… it's just the neophyte at doin' this FCC (flight control computer) stuff, so…a little behind the power curve." P-1 replied "no that's fine, no sweat." P-1 said that he would be shooting for 12 to 14 degrees for $\mathbf{V_2}$ depending on acceleration rate they got after the rotate at 9 degrees. He stated "when you see weight off wheels in the air mode, and positive rate go ahead and get the gear up, okay. Don't wait for me to call it." The pilots then conferred with FTE-1 and agreed to instead wait about a second after the air mode indication so they would have the gear down in the event that the airplane skipped. P-1 said "let make sure we are well clear, it should have a positive rate or a radar altimeter indication by then."

At about 0713 MDT, P-1 performed 9 practice pulls.

(CARD 2C1, L PWR: MTO, R PWR MTO)
[0717 MDT]

Winds: Calm (provided by tower)
Selected $\mathbf{V_1}$: 132 knots
Selected $\mathbf{V_R}$: 134 knots
Selected $\mathbf{V_2}$: 138 knots
Selected $\mathbf{V_{REF}}$: 146 knots
Weight: 95,000 lbs
Selected EPR: MTO

P-1 advanced the power to prepare for takeoff. P-2 asked "If we do an 11 degrees we're gonna abort, correct?" P-1 responded "yes."

After the takeoff, P-1 said "the LPI [sic] is really distracting" (referring to the PLI. The group noted that while in FPA mode, the PLI is referenced to and appears at the flight path marker location, near the bottom of the Attitude Direction Indicator (ADI), instead of near the current pitch attitude indication). About 15 seconds after rotation, FTE-1 asked if the gear was still down, to which P-2 apologized. P-1 commented that it was too late. P-2 raised the landing gear after the altitude alerter sounded (set for at 600 feet AGL). P-1 again commented on the pitch limit indicator stating "that LPI [sic] is just in the way of everything. It just kinda obscures the pitch attitude…something we'll just have to get used to."

FTE-1 reported that the pitch attitude was 10.2 degrees and the column force was 63 pounds (The video group observed an initial pitch of about 9-10 degrees, then 15 degrees during initial climb, then about 20 degrees to maintain $\mathbf{V_2}$+10).

After landing, P-2 said they might have rotated about 2 knots fast, because of the way that he called it. FTE-1 stated that there was a little bit of a bobble on the pitch. P-1 chose to disable FPA mode flight director display for subsequent runs.

(CARD 2C2, L PWR: MTO, R PWR MTO)
[0723 MDT]

Winds: 010 at 2 (provided by tower)
Selected $\mathbf{V_1}$: 132 knots
Selected $\mathbf{V_R}$: 134 knots
Selected $\mathbf{V_2}$: 138 knots
Selected $\mathbf{V_{REF}}$: 146 knots
Weight: 94,400 lbs
Selected EPR: MTO

After the maneuver, P-1 stated that it was going to take a pitch attitude of 20-22 degrees to maintain $\mathbf{V_2}$+10. He asked if they were limiting the pitch to 20 degrees for some reason. FTE-1 said

that if they got to 20 that's enough. They agreed to limit the climb pitch to 20 and FTE-1 said they would take whatever acceleration they got.

FTE-2 reported that the column force was 71 pounds, and FTE-1 reported that there was no bobble, but they were a little shy on the initial pitch. P-1 noted, "by about 0.8 degree." P-1 indicated that he would try to use slightly less force on the next run, and use "more of a ramp." P-2 asked what the actual rotation speed was. FTE-1 said that he did not catch it, and asked TM-3 to provide it. She responded that for card 2C1 it was one knot over (the value for 2C2 was unintelligible). FTE-1 asked FTE-2 how he was doing, since he was "kinda quiet." FTE-2 replied that he was okay, he was just "logging and checking."

At about 0741 MDT, while the airplane was parked on the taxiway paused to allow FTE-1 to confer with FTE-3 via the telephone about which screens to be using on his flight test station, TM-3 confirmed the V-speeds with P-2. P-1 stated they would need to get to almost 20 degrees of pitch to maintain $\mathbf{V_2}$+10. P-2 said that he remembered that from last time with both engines, "it was like you got to the pitch limit and you (didn't/couldn't) pull fast enough, so…" He added "it's really kind of a different animal." P-1 said "…you don't want to pull too much. I think the LPI [sic] is gonna have to be set higher, it comes on too early." He further stated that during a previous partial flap landing at maximum landing weight, it was "up the whole time, *t's not right." P-2 said "they could probably look back through the data for the normal landings and see what our highest normalized AOA is." P-1 said "it's about .64, I think….and the LPI [sic] comes on at .70, but for some reason the AOAs were higher with partial flaps, of course we had bumpy air, that was part of it." P-2 said "* .75 would be better, or something." P-1 said "yeah we're thinking .75 or I'm thinking even .8." P-2 said "or like you said, just set it where the shaker-where the limit is and use it as a cue for the limit. not sure - you know the way we're using it is a holdover from the shaker/pusher concept, instead of 'here's your – here's your limit' maybe with this one, I don't know." P-1 performed 2 practice pulls.

FTE-1 asked FTE-2 or TM-3 to look up the peak pitch rate on the last run. FTE-2 reported that it was 6.5 degrees per second. FTE-1 said they would do another all engine run to see if they could "nail nine." P-1 said that he was going to pull it up to capture V2+10 and it would have to be close to 18, 19 degrees.

(CARD 2C3 L PWR: MTO, R PWR MTO)
[0747 MDT]

Winds: calm
Selected $\mathbf{V_1}$: 131 knots
Selected $\mathbf{V_R}$: 133 knots
Selected $\mathbf{V_2}$: 137 knots
Selected $\mathbf{V_{REF}}$: 145 knots
Weight: 93,300 lbs
Selected EPR: MTO

After the maneuver, P-1 said "there was a bobble on that one" and FTE-1 agreed. FTE-1 reported that the column force was 64 pounds and the pitch attitude got to 9.8 degrees and then went back down to 8.4 degrees. P-1 said "Well darn, let me keep working on it guys, sorry." He further stated "…just keep doing it. Guess I should have practiced more last week." P-1 said "The only thing I can say is you're not gonna be at 9 degrees very long if you want to catch $\mathbf{V_2}$." FTE-1 replied, "yeah I agree, I think for the all engine that's kinda the case." P-1 said "It's like okay we're there and let's move on 'cause it's coming up, here it comes ready or not, 'cuz I'm still overshooting it."

(CARD 2C4 L PWR: MTO, R PWR MTO)
[0752 MDT]

Winds: calm
Selected $\mathbf{V_1}$: 131 knots
Selected $\mathbf{V_R}$: 133 knots
Selected $\mathbf{V_2}$: 137 knots
Selected $\mathbf{V_{REF}}$: 145 knots
Weight: (not verbalized)
Selected EPR: MTO

About 7 seconds after rotation, the background of the airspeed indicator flickered from black to red, and P-1 said "that's about 18, a little shaker." P-2 said, "there's twenty." P-1 said "yeah, there's no way you're gonna maintain it within two knots, the plus ten, I mean we're up at 20 right now. That's what it is." FTE-1 stated "I think you were good on the pitch" and he reported that the peak column force was 57 pounds and it had a little more of a ramp in. P-1 said "well that works to get rid of the bobble, but that may not be what (TM-1) wants."
FTE-1 stated "well, I'd like to do some of these and spend some time looking at it, so. I'll count that one and then we can go on to the engine out ones."

At about 0755 MDT, P-2 said "those antlers (the PLI) again, see we're at .71 AOA." P-1 replied, "Well I'm turning so… " P-2 said "…almost have to have it at about .80 to really not see it." The crew decided to move on to the next test card. They landed the airplane and taxied off the runway for a tire/brake check.

TM-3 said "I have TM-1's review when you're ready" and provided the flight parameters from the last run. The pitch rate was about 5.5 degrees per second and she (TM-1) was looking for more, like 6 or 7, the rotate was good, the column force was 55 pounds, and the pitch was 8.7 degrees. P-1 said he liked the lower pull force, he believed that it made it more repeatable. P-2 asked if there was any bobble and P-1 and FTE-1 said no. P-2 said it was not a set procedure and P-1 said, "well we're trying to develop what we want to tell the feds to use ya know, here's the deal, you know, to get the $\mathbf{V_2}$, $\mathbf{V_2}$+10 with both engines I mean you're gonna need more than 20 degrees, so, we want to knock it off at 20, right?" FTE-1 "yeah, I'm not all that concerned about gettin'…" P-1 interrupted with "I think that's more of an engine out event anyway… you're not at 9 degrees very long if you want to capture that rascal."

P-1 said that he wanted to continue using runway 21 because there was a lower population density off the departure end. P-2 briefly left cockpit for a restroom break.

FTE-1 confirmed that a 55-60 pound pull appeared to be effective.

P-1 confirmed the V-speeds with FTE-1 for the next test, and confirmed that they would try to capture $\mathbf{V_2}$. P-1 was holding the test card with some areas highlighted.

At about 0803 MDT, P-1 briefed the test card 3A1 to P-2. FTE-1 confirmed the V-speeds with FTE-2, and TM-3 confirmed the speeds voluntarily, and provided the wind as 267 at 2.

The flight crew discussed the use of the HUD (P-1 was not using it). P-1 said that he didn't think the HUD was useful for maneuvers involving nose-high attitudes. P-1 considered using the SV, but after looking at it, he decided it would not be appropriate for the test. He said he wanted to have a nice solid pitch attitude and an acceleration cue but he couldn't have both on the same display. He briefed the maneuver again, and said 12 degrees of pitch might work to maintain $\mathbf{V_2}$.

At about 0807 MDT, the crew received clearance to taxi and takeoff. P-1 said to "make real sure on the gear before we bring that up" (raise the landing gear). P-2 said that he had been looking for the three "A's" on the flight controls page display and then waiting about one second before raising the gear. P-1 said "a little positive rate on the radar altimeter." P-2 said "okay."

(CARD 3A1 L PWR:MTO, R PWR: MTO to throttle chop)
[0808 MDT]

Winds: calm
Selected $\mathbf{V_1}$: 130 knots
Selected $\mathbf{V_R}$: 132 knots
Selected $\mathbf{V_2}$: 136 knots
Selected $\mathbf{V_{REF}}$: 146 knots
Weight: 92,000 lbs
Selected EPR: (MTO, then RH to IDLE at $\mathbf{V_1}$-20)

After the maneuver P-1 stated that there was a lot of back pressure at 136 knots. He also stated that it took about 16 degrees to maintain V2 during the climb, and FTE-1 noted that it took about 15 pounds of force to maintain it.

P-1 noted that they would have to shoot for 15 or 16 degrees of pitch to capture V2. He said that he was doing a nice smooth ramp, and "I'm not doing that jerk stuff, anyway it just doesn't work" (with regard to the initial input on the control column). He added "and that's not the way they're going to fly the airplane, and I don't think the FAA's gonna like it either…it's such a great flying airplane, you shouldn't have to abuse it to get the damn thing flying."

FTE-2 reported that the force on the column was about 60 pounds. P-1 said "that works, that's comfortable." P-2 said "so a ramp to 60 worked pretty good."

(CARD 3A2 L PWR:MTO, R PWR: MTO to throttle chop)
[0816 MDT]

Winds: calm
Selected $\mathbf{V_1}$: 129 knots
Selected $\mathbf{V_R}$: 131 knots
Selected $\mathbf{V_2}$: 135 knots
Selected $\mathbf{V_{REF}}$: 144 knots
Weight: (not verbalized)
Selected EPR: (MTO, then RH to IDLE at $\mathbf{V_1}$-20)

TM-3 said that TM-1 asked if the pilots could let the column out a little slower this time. The pilots asked if she meant when capturing the 9 degrees. FTE-1 said "just do the same thing over again."

After the maneuver, during climbout, P-1 said he was trying to find a good pitch angle to maintain a stabilized $\mathbf{V_2}$, and he said that it took 12.5 to 13 degrees of pitch. He added, "but it's pretty dynamic, I mean you're going to overshoot it and then it comes back."

FTE-1 asked "is it taking it a while to accelerate up to $\mathbf{V_2}$, I mean you're holding that pitch I don't know for a couple of seconds it looks like?" P-1 replied "oh no, I was trying to find it, no, it's pretty – it's pretty expeditious we're blowing right through it again, even with one engine. I'm just trying to find what pitch I want to shoot for and it's like 13, 14." P-2 noted while in a standard turn back to the airport, the PLI was showing the whole time. FTE-1 said the ramp input was allowing P-1 to better hit the target pitch. P-1 said he had talked with P-4 about what technique he was using, and it sounded "pretty jerky. I mean he'd come back with it and jerk it forward… you are setting yourself up for bobble city with that one."

FTE-2 reported that the column force was 61.1 pounds. P-1 commented "ok that's good. That's all we need. I don't think we need anything up around the seventies anymore, I think we're done with that." FTE-1 said, "the only thing I'm seeing is, is that when you pause at the pitch I guess you're staying there a little while." P-1 said "yeah, I need to just keep going with it. I mean, that's the thing, we're so intent on capturing that that I'm blowing through $\mathbf{V_2}$." FTE-1 said "yeah." P-1 said "so, you know, it's almost like a continuous maneuver." P-2 echoed "it's a continuous movement." P-1 said "so, I think the idea is though, to get the pitch to get the airplane airborne." FTE-1 said "right." P-1 said "but it's still blowing through $\mathbf{V_2}$ and it's just barely getting off the ground. I think it's just what it is, apparently, the only thing we can fix that, we had a lot of conversations about that is… we talked about an earlier rotation or earlier liftoff, but I think that we're about as slow as we want to go on that I think, unless we're doing VMU testing."

At about 0821 MDT, TM-3 asked if they were going to try it again and P-1 said yes. At about 0825 MDT, TM-3 said they were about 2 knots low on $\mathbf{V_R}$ and 3.5 knots high on the $\mathbf{V_2}$. P-1 said "we're not going to hang out long at 9, we're just going to hit nine and then we're gonna go for the 13 to 14 for $\mathbf{V_2}$." FTE-1 said "yep." P-1 said "it's almost a continuous maneuver." He added that 3 knots above $\mathbf{V_2}$ was not bad, because 2 knots was the criteria. The speed at 35 feet was critical. He said "nine degrees, based on that is a pretty good target…because that's how they're determining their distance."

(CARD 3A3 L PWR:MTO, R PWR: MTO to throttle chop)
[0827 MDT]

Winds: (provided by tower)
Selected $\mathbf{V_1}$: 129 knots
Selected $\mathbf{V_R}$: 131 knots
Selected $\mathbf{V_2}$: 135 knots
Selected $\mathbf{V_{REF}}$: 144 knots
Weight: (not verbalized)
Selected EPR: (MTO, then RH to IDLE at $\mathbf{V_1}$-20)

After the maneuver, FTE-1 said "I think that's it." P-1 said "we're done, I think we caught it there." FTE-1 said "yeah." P-1 said "we must be onto something now." FTE-1 said the airplane was "still pretty heavy" and he thought they would go for the flaps 10 maneuvers and "tomorrow we'll go for score on it." P-1 said he was happy with the nice smooth ramp input and 50-55 pounds force. He added that they were drifting a little bit, but he was not feeding any roll in because he didn't want to "contaminate it" (he may have been referring to the test data or the take-off performance).

At about 0834 MDT, the crew stopped the airplane in the hold short area to discuss the conditions for next run. The crew commented that the V-speeds didn't change much for the change to flaps 10, except that the $\mathbf{V_2}$ actually increased.

P-1 said this time he would rotate until the pitch reached 9 degrees, wait for a positive rate of climb, then capture $\mathbf{V_2}$. He also said that more than 20 degrees of pitch would be required to maintain $\mathbf{V_2}$ with both engines, but he liked the 9 degree pitch target and the rotation technique.

(CARD 6C1 L PWR:MTO, R PWR: MTO)
[0842 MDT]

Winds: calm
Selected $\mathbf{V_1}$: 128 knots
Selected $\mathbf{V_R}$: 130 knots
Selected $\mathbf{V_2}$: 138 knots
Selected $\mathbf{V_{REF}}$: 144 knots
Weight: (not verbalized)
Selected EPR: (MTO)

After the maneuver, P-1 said "you just can't do it within 20 degrees." He asked what the column force was was and said that he must have pulled a little bit more because he overshot a little bit. FTE-1 reported that the column force was 53 pounds and the pitch was 10.5 degrees. TM-3 said she thought they were shooting for nine. FTE-1 said they were. FTE-1 said that IADS (flight test engineer's display software) was malfunctioning and he needed them to clear the runway so he could restart it. He asked FTE-2 to look up the V-speeds for the next run while he dealt with the malfunction, which he did. The airplane was stopped on the ramp from about 0848 to 0853, during this time, P-2 left the cockpit for a restroom break. The airplane then taxied over to the TM trailer to get assistance from technicians. They arrived at the TM trailer at 0857. P-1 left the cockpit for a restroom break at about 0859 GMT.

At about 0905 MDT, P-2 had a conversation with someone (off camera) in the doorway of the cockpit about the desired rotation technique, describing it as a pull to nine, a hesitation, and then an additional pull. Only portions of the conversation could be heard (P-2 was not wearing his headset at this time).

P-1 returned to the cockpit and said, "so, TM-1 is saying we don't want to hang out at 9 degrees very long. Engine-out we gotta just keep it coming." P-2 said "we were just talking about it with (FTE-1). It's almost like it's just like a thought, a goal to go towards, but as soon as you get to it you gotta start pulling again to keep the speed down." P-1 said "yeah." P-2 said "it's like the aggressive pull." P-1 said "yeah." P-2 said "…and then the rest of it."

At about 0908 MDT, the crew began taxiing to the runway, and briefed the details for the next run. They agreed that it would be another all engine run with a pitch target of 9 degrees.

(CARD 6C2 L PWR:MTO, R PWR: MTO)
[0912 MDT]

Winds: 200 at 7
Selected $\mathbf{V_1}$: 127 knots
Selected $\mathbf{V_R}$: 129 knots
Selected $\mathbf{V_2}$: 137 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: 89000 lbs
Selected EPR: (MTO)

During the maneuver, P-1 said "…(looking for) $\mathbf{V_2}$, well you can't really capture it here anyway, but that one (this run) that looked good to me." FTE-1 reported that they had "nailed" the pitch, and the column force was about 56 pounds.

After landing, P-2 said "so which we wanna do next?" FTE-1 responded "well, we were pretty fast at 35 on that one, I'm not sure." P-1 said "yeah, it's got, there's almost ah- there's very little time at 9, you just gotta keep going, you wanna try one more and I'll just pause at 9 and just keep going?" FTE-1 concurred. P-1 said "I'll capture it and boom we're back into it. It's kinda what (TM-1) was saying * the data. Let's try another one….based on what I looked at with (TM-1), its almost ah, you know it's almost a continual rotation. You can target 9, but you don't want to hang out there very long, because it's gonna blow right through it. So it's - now we're into kind of a technique thing here in how we're gonna do this."

FTE-1 said "okay…that's what I was hoping, just spend today just to get something we like." The crew confirmed the airplane configuration, conditions and settings for the next run. FTE-1 said "…so we're targeting 146 (knots) at 35 (feet AGL)."

(CARD 6C3 L PWR:MTO, R PWR: MTO)
[0919 MDT]

Winds: 210 at 5
Selected $\mathbf{V_1}$: 126 knots
Selected $\mathbf{V_R}$: 128 knots
Selected $\mathbf{V_2}$: 136 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: (not verbalized lbs)
Selected EPR: (MTO)

During the maneuver at rotation, P-1 said: "I'm going up, got 9, I'm going up, didn't stay there very long that time." FTE-1 said "yep." P-1 said "see what that does for us." FTE-1 said, "okay that's good." P-1 said "did you like that one?" FTE-1 said "well you didn't stay long, that was better on the pitch." P-1 said, "got nine and just continued on up."

FTE-1 said "…you're six knots fast instead of ten, so that was a lot better. I think that's probably as good as it gets for that." P-1 said "could be, if you want any nine- if you want any pause at nine."

TM-3 said: "speeds were better this time, pitch is a little high." P-1 said "(TM-3), we didn't pause very long at 9. we're trying to capture that V2 at 35, so we're just, it's just not there very long, so. I think that's what you were seeing." FTE-1 said "that helps."

P-2 said "it's really just becoming, I mean especially when it's all engines, a 50 pound pull just to try to get the speed, to get the rate." P-1 said "yeah, I don't even have to think about it anymore, we don't have to be jerking it off the runway or anything."

(At 09:23:38 MDT, the Cockpit Voice Recorder Transcript begins)

FTE-1 said "This time we're going to be doing the card 7 alpha…which is max takeoff power to idle on the right engine, at V1 minus twenty…" P-1 said they would round it off and pull the engine back at 100 knots. P-2 said that the acceleration would be slower acceleration, and asked if he should call VR right at the rotation speed (instead of providing an early callout). P-1 and FTE-1 agree that they should call it at VR. The crew confirmed the configuration, conditions and settings for the next run.

At 09:25:14.7 MDT, FTE-1 said "if you get this one good I'll give you a banana." (Precise time provided for reference to Cockpit Voice Recorder and Flight Data timing information).

(CARD 7A1 L PWR:MTO, R PWR to throttle chop
[0926 MDT]

Winds: 170 at 7
Selected $\mathbf{V_1}$: 126 knots
Selected $\mathbf{V_R}$: 128 knots
Selected $\mathbf{V_2}$: 136 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: 88,200 lbs
Selected EPR: (MTO, then RH throttle to IDLE at 100 knots.)

During the maneuver, the airplane was rotated to 9 or 10 degrees of pitch, held there for a few seconds, then climbed out at about 15 degrees of pitch. The pitch attitude remained very close to PLI, tracking just under it, which is typical for most of the tests documented in this report. P-2 attempted to raise the gear twice before the WOW switches for the main gear went to air mode, and on the third attempt he was able to move the gear handle up. The timing of the attempts is noted below.

0926:20.6 P-1 began to pull back on the column.

0926:23.2 The pitch attitude reached 9 degrees.

0926:24.5 P-2 made an unsuccessful attempt to raise the landing gear handle.

0926:26.4 P-2 made a second unsuccessful attempt to raise the landing gear handle.

0926:26.6 The downlock release for the landing gear handle changed position.
0926:27.4 P-2 made a third, successful attempt to raise the gear.

After the gear handle was raised, the pitch steadily increased above 10 degrees. The crew checked the trim setting (feel of the control column force) while at V2, and found it to be satisfactory. After landing, P-1 said that they could try the same run again, using less of a pause while at the target pitch value. He said "it's almost a continual maneuver then…I can do that, target nine and just keep going. I mean it's I don't know how else we're gonna do it." FTE-1 said "it seems like we were kinda hangin' there for a little bit." P-1 said "well we're pausing, because we're tryin' to do this capture, and I think we're getting too focused on that…. I think it's a target, and then uh 'cause if you have a real engine failure, the guys aren't gonna be lookin at nine degrees, they're gonna be lookin at tryin' to get to V2, they're not gonna be payin' any attention to that, so, that's what I'm thinkin'. It's an abnormal."

(CARD 7A2 L PWR:MTO, R PWR to throttle chop)
[0933 MDT]
(ACCIDENT RUN)

Winds: 156 at 5
Selected $\mathbf{V_1}$: 125 knots
Selected $\mathbf{V_R}$: 127 knots
Selected $\mathbf{V_2}$: 135 knots
Selected $\mathbf{V_{REF}}$: (not verbalized)
Weight: 87,000 lbs
Selected EPR: (MTO, then RH throttle to IDLE at 100 knots.)

09:33:00 P-1 advanced the throttles for takeoff. He flew the takeoff roll with his left hand on the control column and his right hand on the throttle until about 0933:32, when he moved his right hand to the control column.

09:33:37 At about 100 knots, P-2 retarded the RH throttle to the idle position.

09:33:47 At a speed of about 127 knots, P-1 pulled on the control column for rotation, using both hands.

0933:49.6 The pitch attitude reached about 10 degrees.

09:33:50.2 The PLI appears, and the pitch attitude is at or near the PLI.

09:33:50.5 While the pitch attitude was at or near 10 degrees, the wings were level and the slip indicator was displaced slightly to the left.

0933:50.9 P-2 began to point in the direction of the weight on wheels indications on the flight control page shown on display unit 2. The PFD began to register a change in bank and P-1 began to put in a slight left wheel input.

09:33:50.92 The recording ends.

(The Cockpit Voice Recording ended at 09:34:05 MDT)

The group noted that the control wheel and the control column inputs on the accident flight appear to be almost identical to the previous takeoff, until the end of the recording, where the control wheel (left) input increased slightly.