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# STS-134 MOD FRR

## FLIGHT DYNAMICS DIVISION



March 10, 2011

Ray Moreno/ 281-483-8040  
Roger Rojas / 281-483-8026

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# Shuttle CoFR Status Summary

MOD Requirements Codes *	DM	USA FDD
NON-CRITICAL PROC/APPL	G	G
FD-TRAJECTORY	N/A	G
FD-CONSUMABLES (PROP)	N/A	G
FD-ANALYST CERT	N/A	G
FD-CTF	N/A	G
FDF	G	G
EMCC	G	G
CREW TRAINING	G	G
CERTIFIED FLIGHT CONTROLLERS	G	G
CERTIFIED INSTRUCTORS	G	G
FTP-NEW OPS	G	G
FLIGHT ANOMALY RES	G	G
ANOMALY-PROCEDURE	G	G
EX/AI FROM PRIOR READINESS REVIEW	None	None
NO CONSTRAINTS	None	None
LEVEL II (PROGRAM) ACTIONS	None	None
MISSION REQUIREMENTS	G	G
CMD PROC	G	G
EXCEPTION RESOLUTION	G	None
FPPP REQ MET	G	G
CONTRACTOR PROCESS INSIGHT	G	N/A

G	Ready to support flight or standard open work
Y	Non-standard open work with expected resolution
R	Open work without expected resolution
N/A	Does not apply
None	None identified

\* as defined in DA8-020 "MOD Certification of Flight Readiness Process" document  
 Note: CRIT PROC/APPL responsibility has been transitioned to FDOC

## Mission Overview Summary

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Launch/Landing Times	Date	GMT	EDT	
Launch Window Open*	April 19, 2011	23:43:53	19:43:53	(hh:mm:ss)
Launch Window Close		23:53:53	19:53:53	(hh:mm:ss)
Landing Time (KSC)	May 3, 2011	17:27	13:27	(hh:mm)

\* Open of 10 minute window

Consecutive opportunities for FD3 anticipated throughout the launch period (4/19 – 5/3), however there will be visiting vehicle cutouts. ISS altitude strategy is also in work.

**First Stage Design Criteria**     **DOLILU II / High Q**  
**Insertion Altitude/Inclination**     **122 nm / 51.6 deg**

**APM** (above a 5 minute window centered at in-plane)

**I-load Design**                             **1566 lbs**

**Projected APM\*\***                             **1107 lbs**

\*\* Based on 12/21/10 APM simulation and 03/08/11 Green Book

Launch hold capability inside of drainback is dependent upon actual DOL performance.

Abort coverage has sufficient overlap from liftoff to MECO.

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## Significant Changes Since Design Baseline

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- **Launch date change from July 29, 2010 to February 27, 2011 to April 1 to April 19**
  - Current in-plane launch time 23:48:53 GMT (19:48:53 EDT)
- **Mission duration change from 12+1 to 14+1**
  - Due to addition of 4<sup>th</sup> EVA
- **Rendezvous altitude change from 200nmi to 190nmi**
  - Required to increase ascent performance margin
- **FRCS load changed from midpoint to minimum**
  - Required to increase ascent performance margin
- **Removed COPV offload requirement (near full OMS load)**
  - Required to increase ascent performance margin
- **Implemented multi-stage de-orbit for contingency payload return scenarios**
  - Required to increase ascent performance margin
- **New MPS inventory change from R0901S to R1005S**
- **Significant mass properties changes**
  - Middeck increase +1400 lbm; OMS loading change +2100 lbm

## Significant Mission Firsts and Unique Items

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- **DTO 703 Sensor Test for Orion Relative Navigation Risk Mitigation (STORRM)**
  - Post undock re-rendezvous trajectory operations to test Orion-class rendezvous sensors
  - First Shuttle co-elliptic rendezvous profile
  - Teams developed innovative ways to provide state vector updates for onboard targeting for the radar failed case (details in Lead FDO charts)
- **OBSS remaining on ISS (previously performed on STS-123)**
  - Late inspection will be conducted while docked
- **Per program direction, design does not protect for absolute “worst-case forward” scenario where AMS-02 deployed with ELC-3 still in payload bay**
  - Flight Rule ULF6\_C2-79 is in place documenting rationale that if ELC-3 is not deployed, AMS-02 will also not be deployed.
  - Plans are to deploy ELC-3 before AMS-02

# Deviations, Exceedances and Anomalies

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## Deviations/Exceedances

- **No dock contingency return case exceeds the NEOM downweight limit**
  - Will evaluate real-time, if required. (Ascent/Entry Flight Techniques Panel #226, January 19, 2007, and FOICB SR3945)
  - Documented in Flight Rule ULF6\_A4-1
- **GRTLs exceedance of SODB Vol. V Qbar-Nz constraints (for M<5)**
  - Less than required 2 sigma protection indicated by Monte Carlo analysis
  - Data has been provided to Boeing Orbiter SSM – Loads, stress, and analysis
    - Boeing is evaluating constraint applicability (ECD 3/22/11)

## Previous Mission Anomalies (STS-132, STS-133, and OV-105)

- **STS-133 DOLILU weather simulation comparison issue**
  - A 5% miscompare was noted between Boeing's and USA's FWD ET Attach (F01) Load Indicator (4% threshold)
  - SICB approved an update to increase the F01 comparison criteria to 6% as long as the dispersed F01 value is less than or equal to 94% of the structural limit.

# Exceptions and Open Work

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## Exceptions

- None

## Open Work (complete listing in backup charts)

- All open work is scheduled to be completed per standard flight template
- No issues have been identified

## Non-standard Open Work

- Resolution of GRTLS SODB Vol. V exceedance      ECD 3/22/11



## Rescue Mission Status

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**STS-135 has been designated as the LON flight for STS-134**

**STS-135 will be ready to launch on 06/28/11, if required, with the cargo element installed**

**All rescue mission-specific analyses will be performed after call-up**

# Flight Design and Dynamics Readiness Accountability Statement

- Software** : FDD discipline software used to create mission products meets generic and mission-specific Program requirements and is maintained under configuration control in accordance with the appropriate Software Management Plan.
- Flight Software** : All flight software Principal Functions (PFs) owned by FDD are ready for flight. All Discrepancy Reports and Program Notes and Waivers related to USA-owned PFs have been reviewed and appropriately dispositioned for this flight.
- Anomaly Resolution** : All anomalies that could impact mission support have been closed, or have accepted and approved work-arounds in place.
- Production** : All flight reconfiguration products and real-time console support products meet generic and mission-specific Program requirements.
- Operations** : All mission support personnel and instructors are or will be trained, certified and current prior to supporting mission related activities. All flight-specific crew training will be completed prior to launch.

The FDD Flight Readiness Review Process Plan (USA009229) and the Flight Operations Flight Preparation and Readiness Plan (USA008977; Appendix D) which define the processes and products required for a successful flight have been executed and the applicable Program CoFR requirements satisfied.

The undersigned certify that the Flight Design and Dynamics Department, upon satisfactory resolution of any noted exceptions, is ready to support flight STS-134.

<b>Flight Design and Dynamics</b>	<b>D. J. Brockway Acting Director</b>	<i>Original signed by D.J. Brockway</i> Signature	03/01/11 Date
<b>Ascent/Descent Flight Design</b>	<b>J. G. Davis Acting Manager</b>	<i>Original signed by J.G. Davis</i> Signature	03/01/11 date
<b>Orbit Flight Design</b>	<b>R. M. Hill Manager</b>	<i>Original signed by R.M. Hill</i> Signature	03/01/11 date
<b>Navigation &amp; Flight Design Integration</b>	<b>G. E. Schrage Manager</b>	<i>Original signed by G.E. Schrage</i> Signature	03/01/11 date



# DM Flight Design and Dynamics (Trajectory Operations) Significant Mission Firsts and Unique Items

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## ISS Phasing Strategy

- ATV2 Reboost Placeholders: March 18, April 5, 13
  - March 30, April 1 Soyuz 26 Launch and Dock
  - April 19 STS-134 Launch
  - April 26 Progress 41 Undock
  - April 27, 29 Progress 42 Launch and Dock
  - May 16 Soyuz 25 Undock and Landing
- STS-134 Rendezvous altitude: 188.3 nm
- FD3 rendezvous: (Ref: 03/07/11 ISS state vector with 50% atmosphere)
  - April 19 – May 3 4/23-29 cutout due to 42P launch (4/27) and dock (4/29)  
5/3 end of launch period due to 25S (5/16)
- Beta cutout: May 29 – June 17, July 28 – August 14
- Window open on small phase angle days limited by absolute minimum of about 37 deg.

# Significant Mission Firsts and Unique Items

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## Joint Underspeed Recovery Capability

- ISS Thruster:                      ATV2 Orbital Correction System engines
- Full burn:                            ~6.5 mps (21.0 fps) delta velocity
- Propellant                            3210 kg (7076 lbs)
- Maneuver Capability:              ~24 mps  
1.7 burns on FD3 and FD4 (total = 3.4 burns)  
Assumes Service Module would be used to raise ISS altitude after ATV2 undocks
- Maneuver Sequence:              FD3 maneuvers on Daily Orbit 1 and 3, FD4 rndz  
FD4 maneuvers on Daily Orbit 4 and 6, FD5 rndz

## Mated Reboost

- Mated reboost is scheduled on FD10, however, sufficient propellant margin is not expected. Propellant margins will be re-evaluated after docking per standard operations.

# Significant Mission Firsts and Unique Items

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## Orbit Adjust

- Will evaluate the Shuttle entry trajectory based on the March 7, 2011 ISS state vector by Friday March 11, 2011 and publish the results to the FDO website with the launch minus 35 days trajectory delivery.

## No Planned Hardware Jettisons

## No Deployable Payloads

## Payloads of Opportunity

- MAUI, SEITE, SIMPLEX, RAMBO 2

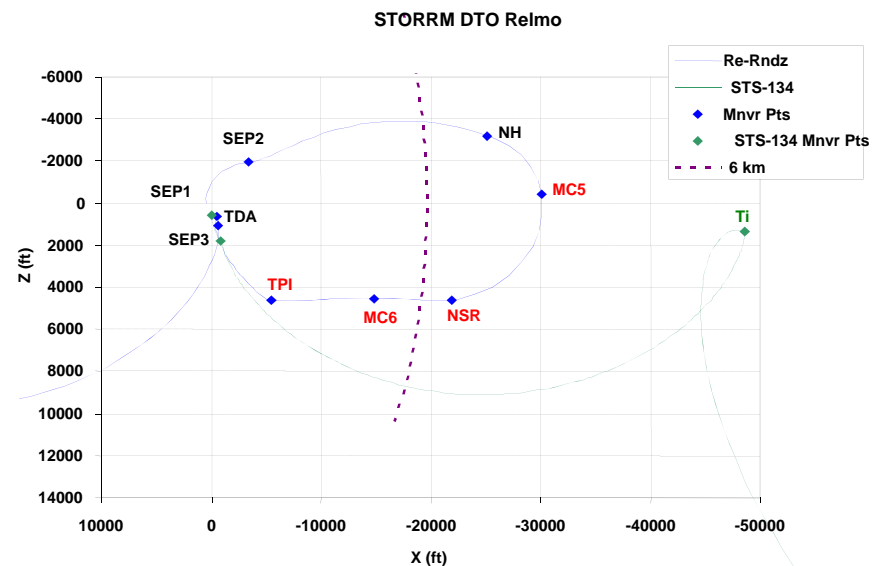
## Development Test Objectives

- DTO 854 Boundary Layer Transition (BLT) Flight Experiment
  - Unique tile manufactured with fixed protuberance height on the underside of port wing
- DTO 703 Sensor Test for Orion Relative navigation Risk Mitigation (STORRM)

## Significant Mission Firsts and Unique Items

### Detail Test Objective (DTO) 703 - Sensor Test for Orion Relative Navigation Risk Mitigation (STORRM)

- DTO 703 will collect sensor data during day-of-rendezvous on FD3 and also during nominal rendezvous and approach. After undock on FD13, data will be collected during undock and separation, and during re-approach using the Orion like “co-elliptic” trajectory. Data will be collected while within a range of 6 km.
- Primary state vector source for the re-rendezvous maneuver targeting is the Ku radar. If Ku radar is unavailable, comparisons to real-time radar data and dispersion analysis show that Orbiter and ISS GPS filtered state vectors are valid sources to perform re-rendezvous maneuver targeting. GPS vectors have never been used for this purpose.



## Significant Mission Firsts and Unique Items

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### Detail Test Objective (DTO) 703 - Sensor Test for Orion Relative Navigation Risk Mitigation (STORRM)

- Detailed console procedures were developed to timeline the responsibilities of each flight controller (FDO, TRAJ, NAV, MARS, Profile, Prox Ops) involved in the Orbiter and ISS state vector generation and uplink process throughout the re-rendezvous phase. These procedures were verified in integrated sims and during realtime undocks (through SEP2) on STS-130, STS-131, STS-132, and STS-133.
- A script known as KATRIOTS was also developed which allows the rendezvous team to use TCS Relative state information (via the RPOP screen) along with the absolute ISS (target) state to create an absolute Orbiter (chaser) state. This can be used as a backup to the GPS state vector generation process, but only for targeting the SEP2 maneuver.
- Trajectory options to recover VNS lighting requirements are also available for delayed undocks when the sun beta angle is less than 5 deg.



# Exceptions and Open Work

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## Exceptions

- None

## Standard Open Work (complete listing in backup charts)

- All open work is scheduled to be completed per standard flight template

## Non-Standard Open Work

- Capture KATRIOTS Script for STS-134 STORRM DTO Support (RTO 3/16)
- Two flight controller proficiencies (ECD 4/4)
  - Backups are available, if required
- No issues have been identified

# STS-134 Flight Dynamics Division Readiness Statement

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The Flight Dynamics Division has performed the reviews necessary to assess the flight readiness relating to flight design requirements definition, crew and flight controller training, and trajectory operations. We have determined all applicable responsibilities acceptable for flight pending closure of the identified open work and issues.

*Original signed by B. Conte*

**Barbara A. Conte**

Chief, Ascent & Descent Dynamics Branch

*Original signed by C. Reichart*

**Christine M. Reichart**

Chief, Orbit Dynamics Branch

*Original signed by R. Gavin for*

**Robert D. Banfield**

Chief, Flight Dynamics Division

As compiled by:

**FDM/R. Moreno**

**FDO/R. Rojas**

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**Pending completion of all standard and non-standard open work, Flight Dynamics is ready for flight.**

# Back-Up

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**Flight Readiness Open Work**

**Propellant Summary**

**FD3 Rendezvous Opportunities (Dot Chart)**

**Separate Back-up File**

- **Launch Window**
- **Abort Regions Chart**
- **Nominal ET Impact Area**

## Flight Readiness Open Work

Item	Responsible	Due Date	Closed	Closure Rationale
<b>USA Flight Design Standard Open Work:</b>				
DATA43 FDD FRR Data Pack	FDM	03/09/11		
PROP37 SODB Volume II Amendment	PROP	03/10/11		
FSW Verification Test Results Review	ADFD	03/18/11	01/31/11	Completed
FSW Verification Test Results Review	Orbit	03/18/11	01/19/11	Completed
RNDZ/FDO Phasing Plan Meeting	Orbit	03/21/11		
DATA45 FDD FSW PF Sign-off	FDM	03/21/11		
ONOR29B RNDZ Launch Target Data	Orbit	03/22/11		
L-4 week LDO Database Freeze	ADFD	03/22/11		
PROP06 OMRSD OMS/RCS	PROP	03/22/11		
PROP07 Abort Propellant Dump Tagup	PROP	03/22/11		
RNDZ08 RNDZ Phasing Limits	Orbit	03/25/11		
PROP02 Mass Properties	PROP	03/25/11		
Prop Analyst & Flt Controller Tag-up	PROP	03/28/11		
ONOR37B Daily Planar/Phase Windows	Orbit	03/29/11		
ASCT04 Uplink APM	ADFD	03/29/11		
NAVO16B GPO COTM Data Pack	Navigation	03/29/11		
NAVO18B GPO/ONAV Ops Memo	Navigation	03/29/11		

## Flight Readiness Open Work - Continued

Work Item	Responsible	Due Date	Closed	Closure Rationale
<b>USA Flight Design Standard Open Work - Continued:</b>				
LDO: L-3 week LDO Checkout/TCDT Sim	ADFD	03/31/11		
ONOR27 Launch and Landing Data	Orbit	03/31/11		
ASCT44 DOL Uplink I-loads	ADFD	04/04/11		
ONOR29C RNDZ Launch Target Data	Orbit	04/11/11		
Dial Down Decision FIDP	FDM	04/11/11		
PERA Pre-Flight Product	ADFD	04/12/11		
DSCT17 Landing Site Tables	ADFD	04/12/11		
RNDZ02 Target Drag Characteristics	Orbit	04/12/11		
PROP00A PROP/Ascent Aborts Tagup	PROP	04/12/11		
Flight Annex	Navigation	04/12/11		
ONOR37C Daily Planar/Phase Windows	Orbit	04/13/11		
ASCT99 OMS Assist - ATO Update	ADFD	04/13/11		
RNDZ09 Rendezvous COLA Plans	Orbit	04/14/11		
C-Band tracking Scheduling Message	Navigation	04/14/11		

## Flight Readiness Open Work - Continued

Work Item	Responsible	Due Date	Closed	Closure Rationale
<b>USA Flight Design Standard Open Work - Continued:</b>				
PROP02A DOL Mass Properties Updates	PROP	04/14/11		
Prelaunch mass properties request	PROP	04/14/11		
PROP31 ARD Data	PROP	04/14/11		
PROP33 Ferry Data Package	PROP	04/14/11		
PROP34 MCC Data	PROP	04/14/11		
SRB & ET RTLS Impact Point Update Memo	ADFD	04/16/11		
ASCT42 Collision Avoidance Data	ADFD	04/16/11		
ASCT47 Final MCC Trajectory Inputs	ADFD	04/16/11		
DSCT66 Real-Time Support Files	ADFD	04/16/11		
Range Safety Launch Window Cutout	ADFD	04/16/11		
ASAB32B AME MCC Support Tables	ADFD	04/17/11		
L-2 day DOLILU System Checkout	ADFD	04/17/11		
DSCT05 Maximum Crossrange Capability	ADFD	04/17/11		
ASAB25 ARD Bias Tables	ADFD	04/18/11		

## Flight Readiness Open Work - Continued

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Work Item	Responsible	Due Date	Closed	Closure Rationale
<b>USA Flight Design Non-Standard Open Work:</b>				
Resolution of GRTLS SODB Vol. V Exceedance	ADFD	3/22/11		



## Flight Readiness Open Work - Continued

Item	Responsible	Due Date	Closed	Closure Rationale/Status
<b>Trajectory Operations Standard Open Work</b>				
Close to Launch Trajectory Data	OFDO	03/18/11		
TCDT Checkout in Ops Cert Mode	AE GPO	04/03/11		
DOD Support Readiness	LSO	04/04/11		
Flight Load Checklist Complete	Nav	04/04/11		
Flight Load Checklist Complete	DOLILU	04/04/11		
Flight Load Checklist Complete	Entry Support	04/04/11		
Flight Load Checklist Complete	Orbit-RNDZ	04/04/11		
Successful Completion of RNDZ Training	RNDZ Instructor	04/06/11		
Flight Load Checklist Complete	RGPO	04/13/11		
Flight Load Checklist Complete	AE FDO	04/13/11		
Flight Load Checklist Complete	AE GPO	04/13/11		
Flight Load Checklist Complete	LSO	04/13/11		
Flight Load Checklist Complete	OFDO	04/13/11		
<b>Trajectory Operations Non-Standard Work:</b>				
Capture KATRIOTS Script for STS-134 STORRM DTO Support	OFDO	03/16/11		

## Flight Readiness Open Work - Concluded

Item	Responsible	Due Date	Closed	Closure Rationale/Status
<b>Trajectory Operations Non-Standard Work:</b>				
ORBIT 2 TRAJ position proficiency	OFDO	04/04/11		
ORBIT 4 TRAJ position proficiency	OFDO	04/04/11		
<b>DM Standard Open Work:</b>				
Orbiter Readiness Statement	DM	03/30/11		
Range Safety Readiness Statement	DM	04/03/11		

The Flight Design and Dynamics Division has performed a final review and determined all Division and USA FDD open work and/or actions for this mission are closed or acceptable rationale is provided for proceeding with the flight.

\_\_\_\_\_  
Flight Design Manager

Date\_\_\_\_\_

\_\_\_\_\_  
STS Integration Manager

Date\_\_\_\_\_

\_\_\_\_\_  
Director, Flight Design and Dynamics Department

Date\_\_\_\_\_

\_\_\_\_\_  
Chief, Flight Dynamics Division

Date\_\_\_\_\_

## Propellant Summary

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**OMRSD Propellant Loading Quantities will be delivered on or before March 22, 2011.**

**FRCS = 1912 lbm**

**ARCS = 4970 lbm**

**OMS = 24860 lbm**

**FRR Design Propellant Margins**

**ARCS/OMS = 22 lbm**

**FRCS = 0 lbm**

**FRR Design Assumptions: STS-134 ATL, FRR Cycle Trajectory Inputs - 190 nm RNDZ, 170 sec OMS Assist, 1 mated water dump**

## FD3 Rendezvous Opportunities (Dot Chart)

