

STS-135 MOD FRR

FLIGHT DYNAMICS DIVISION



June 14, 2011

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- None Special Topics
- None Issues and Concerns
- X Exceptions and Open Work
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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	None	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

Launch/Landing Times	Date	GMT	EDT	
Launch Window Open	July 8, 2011	15:21:46	11:21:46	(hh:mm:ss)
Launch Window Close		15:31:46	11:31:46	(hh:mm:ss)
Landing Time (KSC)	July 20, 2011	11:07	07:07	(hh:mm)

- FD3 rendezvous opportunities are anticipated for every day in the July launch period
- Beta angle cut-out ($|\beta| > 60^\circ$) occurs for launch dates from August 1st through August 15th

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 **874 lbs**

Projected APM* **1229 lbs**

- * Based on 5/10 APM simulation and 6/07 greenbook (includes FRCS load increase)
- Launch hold capability inside of drainback is dependent upon actual DOL performance
 - Abort coverage has sufficient overlap from liftoff to MECO

Significant Changes Since Design Baseline

- **Authorized the STS-135 mission**
 - Updated the flight designation from STS-335/LON to STS-135/ULF7
 - Updated the crew size from 4 up / 10 down to 4 up / 4 down
- **Manifested the Pico-Satellite Solar Cell (PSSC) experiment**
 - Details in “Special Topics”
- **Updated rendezvous altitude from 205 nmi to 215 nmi**
 - Assumed ISS reboost using all available ATV propellant prior to ATV undock
 - Actual rendezvous altitude is expected to be lower than 215 nmi
- **Modified Shuttle flyaround to obtain high-resolution imagery of the port and starboard sides of the ISS**
 - Details in “Special Topics”
- **Implemented multi-stage de-orbit for contingency payload return scenarios**
 - Required to increase ascent performance margin
- **Changes to be incorporated in the Uplink cycle**
 - Launch date change to July 8th
 - Forward RCS load increase to midpoint

Significant Mission Firsts and Unique Items

- **First flight of the modified shuttle flyaround**
- **Crew rescue, if required, would be accomplished by a phased crew return via Soyuz**

Deviations, Exceedances and Anomalies

Deviation / Exceedances

- **A Contingency Abort Black Zone (CABZ) assessment was performed**
 - Mass properties exceeded the CABZ assessment criteria (liftoff weight >259,000 lbm and Xcg aft of 1115.0 in.)
 - FRR cycle liftoff weight = 266,090 lbs. and Xcg = 1,119.7 in.
 - Results are similar to STS-128 with the exception of a small 2EO ECAL black zone (<10 sec)
 - Loading FRCS to midpoint will shift the Xcg forward, which should provide some improvement
 - Flight Directors and Flight Manager agreed that no changes will be made

Previous Mission Anomalies

- None

Significant ARs and Disposition

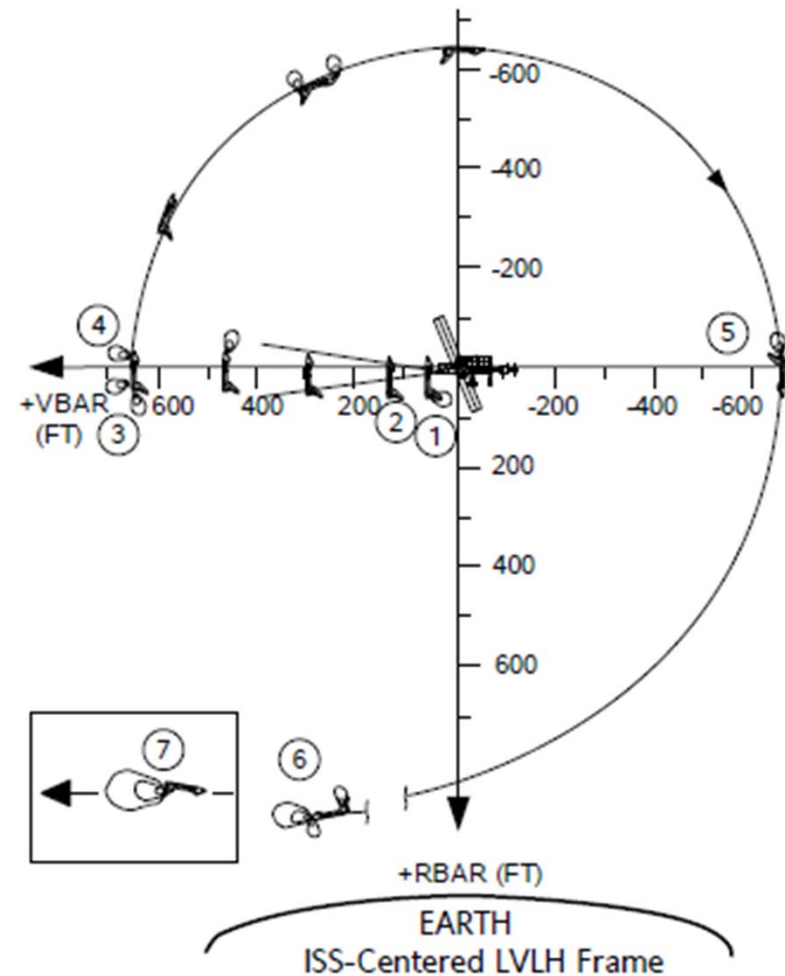
- None

Special Topics

Modified Shuttle Flyaround

- If propulsive consumables permit, the ISSP desires an imagery survey of the ISS port and starboard exterior surfaces by means of a Shuttle flyaround at a distance of 600 ft
- Undocking time will be chosen to provide adequate lighting for imagery
- ISS will maneuver to a +/-Y into the velocity vector (YVV) attitude after Shuttle undocking
- Twice Orbital Rate Flyaround (TORF) begins between 600 and 700 ft CG to CG
- Flyaround reduced to 1/2-lap to minimize timeline impacts of new separation profile
- If ISS is unable to maneuver, the standard 1-lap flyaround can be performed

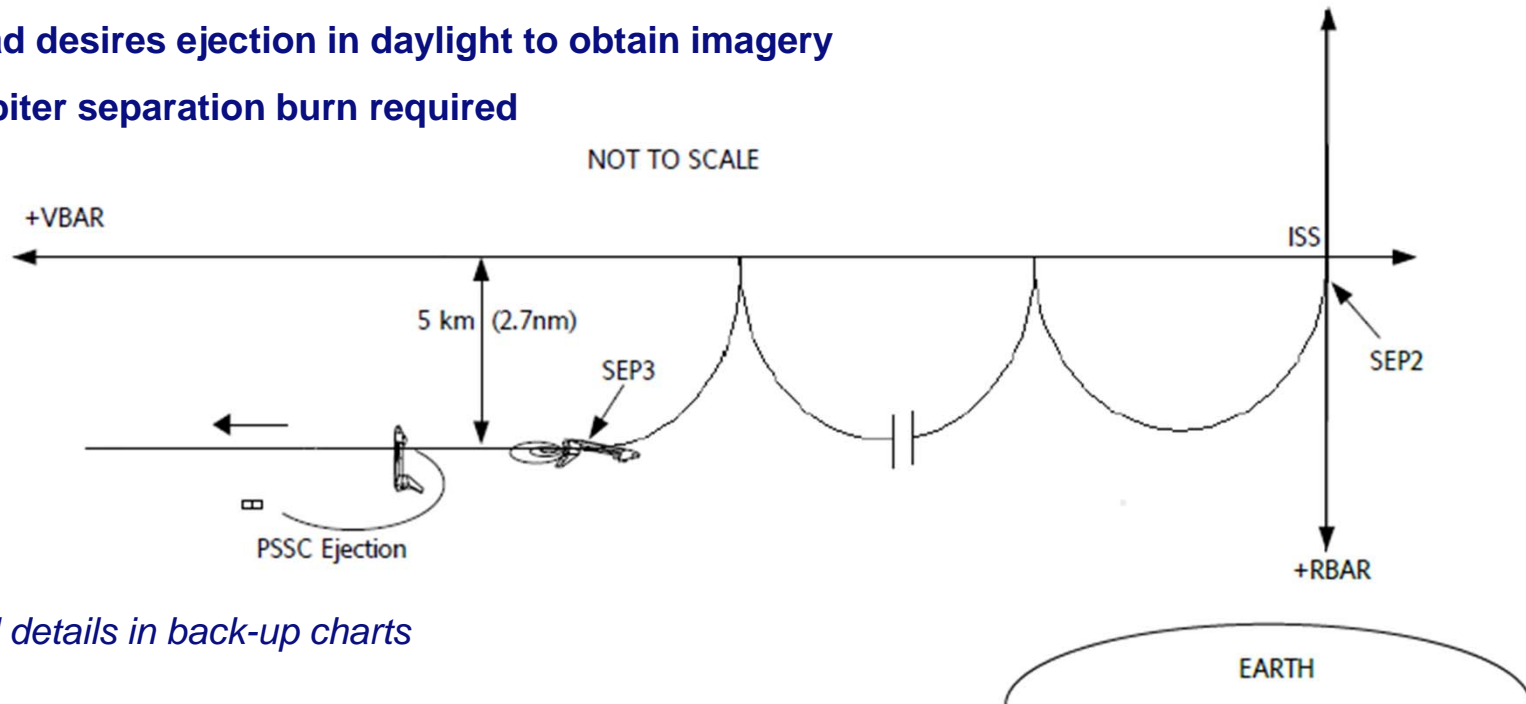
Additional details in back-up charts



Special Topics (concluded)

Pico-Satellite Solar Cell (PSSC) Payload

- PSSC satellite will be ejected retrograde along the Orbiter $-Z$ axis on the day after undocking
- Trajectory Operations Officer requires co-elliptic orbit at least 5 km (2.7nm) below ISS to preclude long-term recontact issues
- Payload desires ejection in daylight to obtain imagery
- No Orbiter separation burn required



Additional details in back-up charts

CAF Open Work Summary

Exceptions

- None

Standard

- All open work is scheduled to be completed per standard flight template
- Open work table in backup pages

Non-standard

- None

Flight Design and Dynamics Readiness Accountability Statement

☑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-135.

Flight Design and Dynamics	D. J. Brockway Acting Director	<i>Original signed by D. J. Brockway</i> Signature	05/16/2011
Ascent/Descent Flight Design	J. G. Davis Acting Manager	<i>Original signed by J. G. Davis</i> Signature	05/16/2011
Orbit Flight Design	R. M. Hill Manager	<i>Original signed by R. M. Hill</i> Signature	05/16/2011
Navigation & Flight Design Integration	G. E. Schrage Manager	<i>Original signed by G. E. Schrage</i> Signature	05/16/2011

Flight Design and Dynamics Declaration of Compliance with CoFR Endorsement Requirements for STS-135 Flight Readiness

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.

Requirements Compliance: All requirements defined by the documents below (as required by the FIDP Compliance Matrix) have been or will be satisfied prior to flight.

<u>DOCUMENT</u>	<u>VERSION</u>	<u>DATE</u>
Flight Implementation Data Pack (FIDP) - Generic	GEN-MZ	5/17/2011
Flight Implementation Data Pack (FIDP) - Flight Specific	135-BASE-L	5/26/2011

Waivers & Exceptions:

None

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.

Pending completion of open work and closure of noted exceptions, if applicable, Flight Design & Dynamics is ready to support STS-135.

Original signed by D. J. Brockway 6/01/2011

Director **Date**
Flight Design & Dynamics

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

ISS Phasing Strategy

- ATV2 Reboost Placeholders: 6/2, 6/12 (x2), 6/15 (x2)
 - 6/7, 6/9 Soyuz 27 Launch and Dock
 - 6/20 ATV2 Undock and re-entry
 - 6/21, 6/23 Progress 43 Launch and dock
- 43P Reboost Placeholders: 6/29, 7/5
- Expected Rendezvous Altitude: 210.6 nm
- Max Rendezvous Altitude: 215 nm
- Window open on small phase angle days limited by absolute minimum of 39 deg.

Significant Mission Firsts and Unique Items (cont.)

Joint Underspeed Recovery Capability

- ISS Thruster: Progress 43 8R&D engines
- Delta-V: ~4 mps (~13 fps) per burn
- Propellant TBD lbs total (may be limited to two 2000 sec and one 1000 sec JURE burns)
- Maneuver Capability: 2 burns on FD3 and 1 or 2 on FD4
- Maneuver Sequence: FD3 maneuvers on Daily Orbit 1 and 3
FD4 maneuvers on Daily Orbit 1 and 3 (possibly, if a second burn is available)

Mated Reboost

- The STS-135/ULF7 timeline does not currently contain a placeholder for mated reboost.

Orbit Adjust

- For a July 8th launch, an orbit adjust may be required to obtain a second deorbit opportunity to KSC on EOM.

Significant Mission Firsts and Unique Items (conc.)

No Planned Hardware Jettisons

Payloads of Opportunity

- MAUI, SEITE, SIMPLEX, RAMBO 2

Exceptions and Open Work

Exceptions

- None

Standard Open Work

- Remaining Integrated Sims
- CTL Trajectory Data (L-35 & L-7)
- TCDT Checkout in Ops Cert Mode (L-15)
- Remaining Crew Rendezvous Standalone Lessons (L-10)
- DOD Support Readiness (L-10)
- PERA Pre-Flight Product (DM42 PERA Lead) (L-7)
- EMCC #2 Checkout (L-7)
- Flight Load Checkouts
 - Orbit , Ascent, A/E GPO, Entry, LSO (L-7)

STS-135 Flight Dynamics Division Readiness Statement

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 Barbara A. Conte

Barbara A. Conte

Chief, Ascent & Descent Dynamics Branch

Original signed by Christine M. Reichert

Christine M. Reichert

Chief, Orbit Dynamics Branch

Original signed by Robert D. Banfield

Robert D. Banfield

Chief, Flight Dynamics Division

As compiled by:

FDM/Dawn G. Kyle

FDO/Mark B. Anderson

Back-Up Charts

Flight Readiness Open Work

Propellant Summary

Launch Window

Proximity Operations Details

- **Modified Flyaround**
- **Pico-Satellite Solar Cell Payload**

Abort Regions

Nominal ET Impact Area

Flight Readiness Open Work

Work Item	Responsible	Due Date	Closed	Closure Rationale
USA Flight Design Standard Open Work:				
PROP37 SODB Volume II Amendment	PROP	5/19/11	5/19/11	Delivered
DATA43 FDD FRR Data Pack	FDM	5/23/11	5/19/11	Delivered
DSCT28 Recovery Prebank	ADFD	5/26/11	5/26/11	Redelivered for launch slip
FSW Verification Test Results Review	Orbit	5/27/11	5/23/11	Completed
FSW Verification Test Results Review	ADFD	5/29/11	5/26/11	Completed
DATA09 Flight Data File Inputs	SDM	5/31/11	5/31/11	Redelivered for DSCT28
RNDZ/FDO Phasing Plan Meeting	Orbit	6/08/11	6/01/11	Completed
ONOR29B RNDZ Launch Target Data	Orbit	6/08/11	6/07/11	Delivered
DATA45 FDD FSW PF Sign-off	FDM	6/09/11	5/26/11	Delivered
PROP06 OMRSD OMS/RCS	PROP	5/31/11	5/19/11	Delivered
PROP07 Abort Propellant Dump Tagup	PROP	6/10/11		
L-4 week LDO Database Freeze	ADFD	6/10/11		
RNDZ08 RNDZ Phasing Limits	Orbit	6/13/11		
PROP02 Mass Properties	PROP	6/15/11		
Prop Analyst & Flt Controller Tag-up	PROP	6/16/11		
ONOR37B Daily Planar/Phase Windows	Orbit	6/15/11		

Flight Readiness Open Work - Continued

Work Item	Responsible	Due Date	Closed	Closure Rationale
USA Flight Design Standard Open Work - Continued:				
ASCT04 Uplink APM	ADFD	6/17/11		
NAVO16B GPO COTM Data Pack	Navigation	6/17/11		
NAVO18B GPO/ONAV Ops Memo	Navigation	6/17/11		
ONOR27 Launch and Landing Data	Orbit	6/17/11		
LDO: L-3 week LDO Checkout/TCDT Sim	ADFD	6/23/11		
ASCT44 DOL Uplink I-loads	ADFD	6/23/11		
ONOR29C RNDZ Launch Target Data	Orbit	6/28/11		
Dial Down Decision FIDP	FDM	6/29/11		
PROP00A PROP/Ascent Aborts Tagup	PROP	6/30/11		
ONOR37C Daily Planar/Phase Windows	Orbit	6/30/11		
PERA Pre-Flight Product	ADFD	7/01/11		
DSCT17 Landing Site Tables	ADFD	7/01/11		
RNDZ02 Target Drag Characteristics	Orbit	7/01/11		
RNDZ09 Rendezvous COLA Plans	Orbit	7/01/11		
ASCT99 OMS Assist - ATO Update	ADFD	7/02/11		
PROP33 Ferry Data Package	PROP	7/02/11		

Flight Readiness Open Work - Continued

Work Item	Responsible	Due Date	Closed	Closure Rationale
USA Flight Design Standard Open Work - Continued:				
PROP34 MCC Data	PROP	7/02/11		
C-Band tracking Scheduling Message	Navigation	7/03/11		
PROP02A DOL Mass Properties Updates	PROP	7/03/11		
Prelaunch mass properties request	PROP	7/03/11		
PROP31 ARD Data	PROP	7/03/11		
SRB & ET RTLS Impact Point Update Memo	ADFD	7/05/11		
ASCT42 Collision Avoidance Data	ADFD	7/05/11		
ASCT47 Final MCC Trajectory Inputs	ADFD	7/05/11		
DSCT66 Real-Time Support Files	ADFD	7/05/11		
Range Safety Launch Window Cutout	ADFD	7/05/11		
Flight Annex	Navigation	7/05/11		
ASAB32B AME MCC Support Tables	ADFD	7/06/11		
L-2 day DOLILU System Checkout	ADFD	7/06/11		
DSCT05 Maximum Crossrange Capability	ADFD	7/06/11		
ASAB25 ARD Bias Tables	ADFD	7/07/11		

Flight Readiness Open Work - Continued

Work Item	Responsible	Due Date	Closed	Closure Rationale
USA Flight Design Non-Standard Open Work:				
None				

Flight Readiness Open Work - Continued

Item	Responsible	Due Date	Closed	Closure Rationale/Status
Trajectory Operations Standard Open Work				
Close to Launch Trajectory Data	OFDO	6/03/11	6/02/11	Published
TCDT Checkout in Ops Cert Mode	AE GPO	6/23/11		
Flight Load Checklist Complete	Nav	6/23/11		
Flight Load Checklist Complete	DOLILU	6/23/11		
Flight Load Checklist Complete	Entry Support	6/23/11		
Flight Load Checklist Complete	Orbit-RNDZ	6/23/11		
Successful Completion of RNDZ Training	RNDZ Instructor	6/28/11		
DOD Support Readiness	LSO	6/29/11		
Flight Load Checklist Complete	RGPO	7/01/11		
Flight Load Checklist Complete	AE FDO	7/01/11		
Flight Load Checklist Complete	AE GPO	7/01/11		
Flight Load Checklist Complete	LSO	7/01/11		
Flight Load Checklist Complete	OFDO	7/01/11		
Trajectory Operations Non-Standard Work:				
CABZ Review with Flight Directors	AE GPO	5/26/11	5/26/11	DA8 concurred with no changes
Certification – Orbit 3 FDO (STS-134 OJT)	OFDO	TBD	5/19/11	certified

Flight Readiness Open Work - Concluded

Item	Responsible	Due Date	Closed	Closure Rationale/Status
DM Standard Open Work:				
Orbiter Readiness Statement	DM	6/18/11	6/08/11	Completed
Range Safety Readiness Statement	DM	6/22/11		

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

OMRSD Propellant Loading Quantities were delivered on May 19, 2011.

FRCS = 2175 lbm

ARCS = 4970 lbm

OMS = 24860 lbm

FRR Design Propellant Margins

ARCS/OMS = 31 lbm

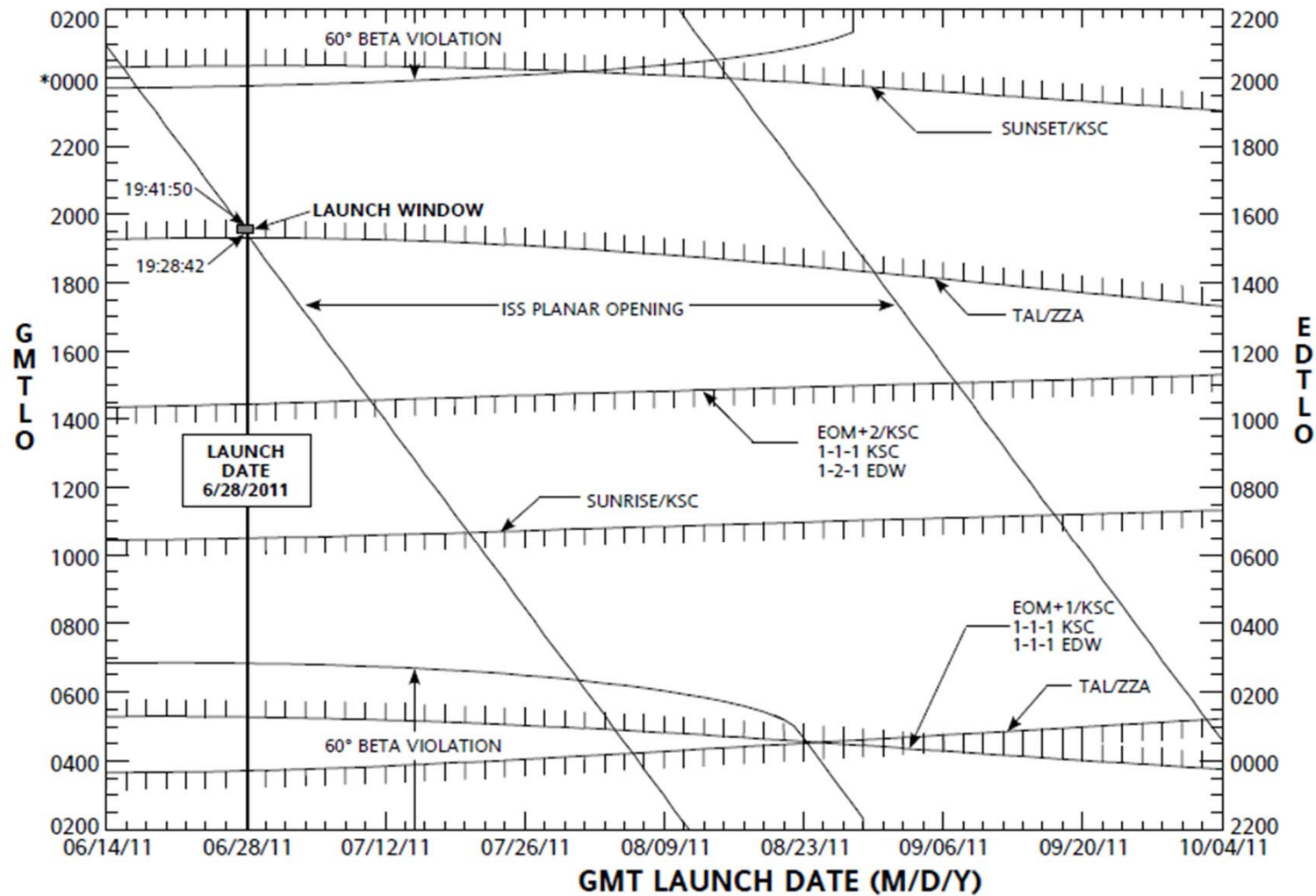
FRCS = 258 lbm

**FRR Design Assumptions: STS-135 ATL, FRR Cycle Trajectory Inputs - 215 nm
RNDZ, 88 sec OMS Assist, 0 mated water dumps**

Mission Duration = 12+0+2
 Inclination = 51.6°
 OMS2 ha/hp = 124 x 85 nmi.
 Target ha/hp = 220 x 210 nmi.

STS-135 FRR LAUNCH WINDOW

C. Oliver/USH-483L
 D. Brownfield/USH-483L



Note: EOM lighting lines, based on an OMS2 phase angle of 253 deg, are representative only.
 The ISS beta angle ($|\beta| < 60^\circ$) for mated operations is beginning ~ 1/23:45:51 MET (FD3 Rendezvous) and ending ~ 9/14:45:00 MET.
 * indicates the dateline. Launch times above this point are on subsequent days from the date indicated on the corresponding date axis.

STS-135 FRR

PROXIMITY OPERATIONS DESIGN CHANGES

J. LoPresti-Bellock/USH-483L
G. Bartz/USH-483L

APPROACH

- No changes

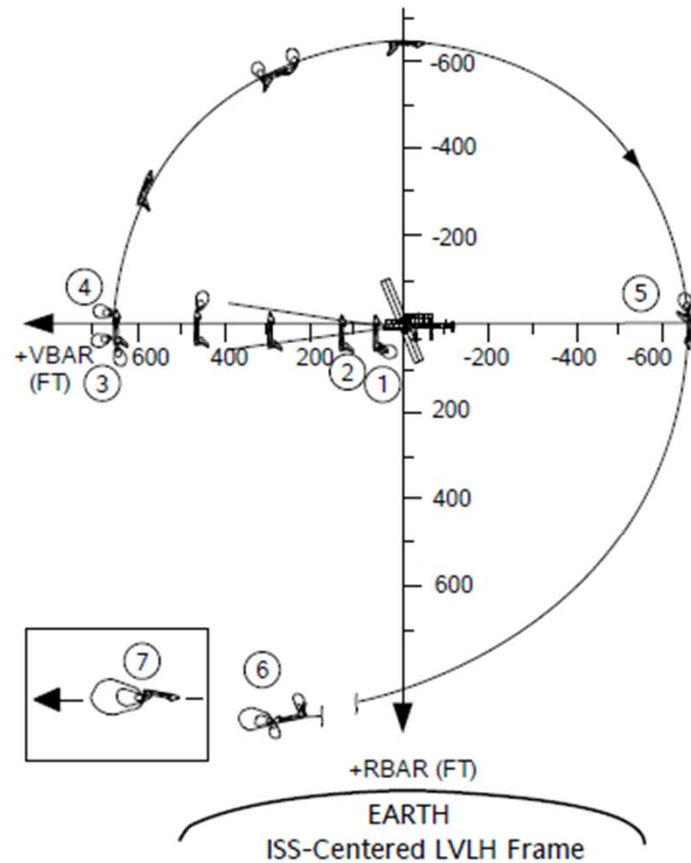
SEPARATION

- The ISS highly desires an imagery survey of the ISS port and starboard exterior surfaces by means of a Shuttle flyaround at a distance of 600 ft, if propulsive consumables permit
- The ISS will maneuver to a +/-Y into the velocity vector (YVV) attitude after Shuttle undocking
- Undock time chosen for lighting during port and starboard imagery
 - Undock window open = sunrise – 59 minutes
 - Sunrise occurs at ½-lap flyaround start
 - ISS is considering a requirement to maneuver in darkness to avoid array longeron shadowing
 - Undock window close = sunset – 87 minutes
 - Sunset occurs at 5 minutes after end of ½-lap flyaround
- Opening rate outside 30 ft changed from >0.2 to >0.3 fps due to timeline issues
- Protects 27 minutes of stationkeeping while ISS maneuvers to -YVV for positive beta (+YVV for negative beta)
- **Twice Orbital Rate Flyaround (TORF)** begins between 600 and 700 ft CG to CG
 - Flyaround reduced to ½-lap to minimize timeline impacts of new separation profile
- SEP1 after ½-lap flyaround on -Vbar
- SEP2 burn performed in an attitude to avoid radial components from the large retrograde burn
- SEP3 burn performed the day after undocking due to timeline issues and burned as single OMS
- If ISS is unable to maneuver, separation profile will revert to standard with 1-lap flyaround
 - SEP2 burn changed to +X
 - SEP3 burn the next day changed to -X

STS-135 FRR

J. LoPresti-Bellock/USH-483L
G. Bartz/USH-483L

UNDOCKING, STATIONKEEPING, TORF, AND FINAL SEPARATION



	UNDOCK ET (h:mm)	Range (ft) DP - DP	EVENT
	-0:03	0	ORBITER AND ISS IN FREE DRIFT TO BEGIN UNHOOKING (ISS LVLH PYR 0, 0, 0 ATTITUDE)
1	0:00	0 2	UNDOCKING DAP B9/ALT; MODE TO LVLH; MAINTAIN CORRIDOR
	0:01		SELECT VERN; PERFORM DAP B +Z NORMZ BURNS AT 10 SEC INTERVALS TO BUILD OPENING RATE TO 0.15 FPS
	>0:03	>30	DAP B +Z NORMZ BURNS AT 10 SEC INTERVALS TO BUILD OPENING RATE GREATER THAN 0.3 FPS
		50	RESELECT -X JETS
2	0:05	75	TRANSITION TO LOWZ
3	0:32	>600 (CG-CG)	ISS 90 DEG YAW TO +/-YVV IN APPROX. 27 MIN ORBITER MODES TO AUTO AND BEGINS STATIONKEEPING NEAR 650 FT
4	0:59	~650 (CG-CG)	BEGIN 1/2-LAP TORF BETWEEN 600 FT AND 700 FT
5	1:22		SEP1: 1.5 FPS +X RADIAL DOWN BURN
6	1:50	>6000 (CG-CG)	SEP2: 7 FPS -X, NORMZ RETROGRADE BURN IN A7/B7 (ORBITER LVLH PYR -12, 0, 0 ATTITUDE)
7	NEXT DAY		SEP3: 7 FPS RIGHT OMS RETROGRADE BURN

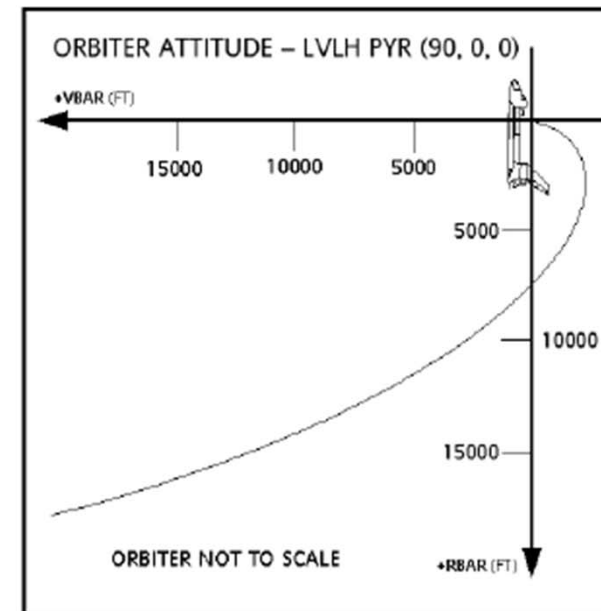
PROXIMITY OPERATIONS DESIGN CHANGES (CONTINUED)

PICOSAT SOLAR CELL (PSSC) PAYLOAD ADDED

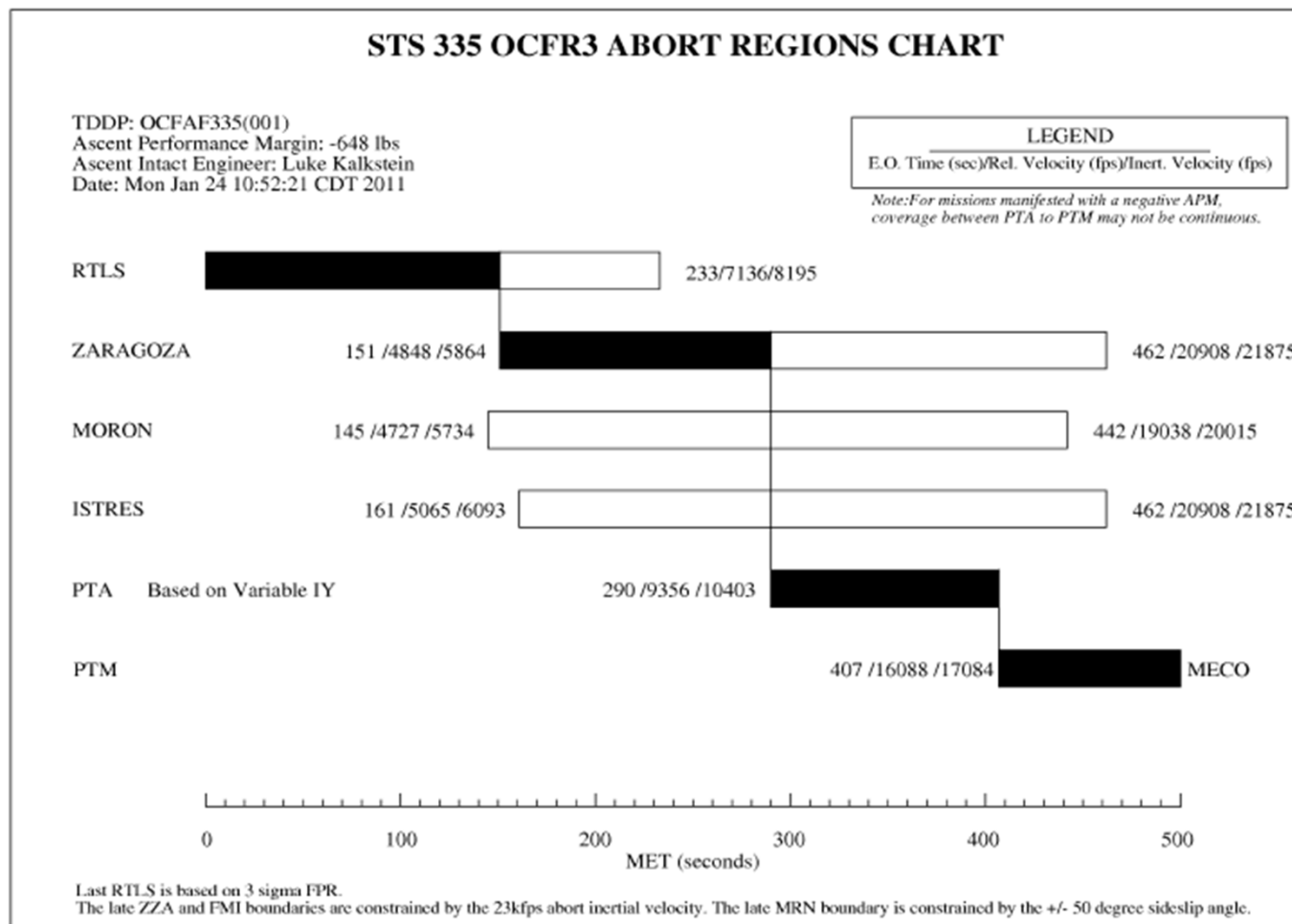
- PSSC experiment is a satellite that is ejected the day after undocking
- Includes four small solid rocket motors
- SEP2 and SEP3 burns sized to be 7 fps retrograde to lower both sides of orbit prior to payload ejection
 - Protects ISS from long-term recontact concerns with PSSC
 - Trajectory Operations Officer (TOPO) requires co-elliptic orbit at least 5 km (2.7nm) below ISS
 - Burns sized to also protect for velocity changes due to late inspection maneuvers, RCS hot fire, and FCS checkout between SEP2 and SEP3

PSSC EJECTION

- PSSC ejected 30 minutes after SEP3 burn per timeline
- Desires ejection in daylight to obtain imagery
 - Sunrise+10 to Sunset-10 minutes preferred
 - Tight timeline may not support
- Orbiter Boom/Sensor System (OBSS) required to be rolled out for payload ejection
- No payload pointing requirement
- Ejection time and Orbiter rotation about the ejection vector can be optimized real-time for lighting and communications
- Orbiter in free drift 2 minutes before and after ejection
- Ejected retrograde along Orbiter -Z axis
- No Orbiter separation burn required
 - 6.6 fps (2.0 mps) PSSC ejection velocity is sufficient



STS-135 Abort Regions Chart



Note: Due to inherent assumptions made in its creation, this chart may not accurately depict DOL conditions and intact abort boundary times.

Nominal ET Impact Area

