



# Proposed Combined C2/C3 Mission Assessment

---

NASA Advisory Council/Space Operations Committee

5/3/2011

Kathryn Lueders



# Agenda

---

- **Background**
- **NASA C2/C3 Assessment Plan**
- **Overview C2 C3 Mission Profile and Objectives**
- **Forward Work**



# Background

---

- FY10, SpaceX approached the Commercial Crew and Cargo Program Office for approval to include the current C3 mission objectives as secondary/get ahead objectives on the C2 mission.
- NASA decided to defer any decision on a combined mission until after the successful launch of the C1 mission.
- In January 2011, ON/QA provided a set of minimum data needed by NASA to make a combined mission decision (Impact and Risk Assessment)
- Additionally, SpaceX/NASA began discussing impacts to a proposed SpaceX commercial secondary payload flying on C2 (Combined C2 C3 Mission).
- Currently C3PO does not plan to modify the current SAA to delete a flight.
  - If all objectives of C3 mission can be accomplished on C2 flight; then C3PO would be able to agree that the C3 milestones have been accomplished
  - If all objectives of C3 mission were not met, SpaceX would need to do a re-flight.



# ISS Mission Assessment Approach

---

## **Minimum data required in order to assess the Combined Mission:**

- 1. Final C2/C3 Vehicle Design Baseline and/or clear schedule for any open design areas**
  - 2. Jointly agreed Verification and Test Plans and/or clear schedules for any open verification items**
    - Verification and Test Plans defined for SSP 50808 requirements
    - Agreements on additional testing and risk mitigation required due to elimination of separate C2 mission
  - 3. Jointly agreed to combined C2/C3 Mission Profile and objectives**
  - 4. Review of C1 Post Flight Report**
- NASA/SpaceX have developed a plan to meet the objectives and provide the data and risk assessments required to make combined C2 C3 Mission decision in June.



# High Level Combined C2/C3 Mission Assessment Plan

Milestone	Date	Forum
SpaceX Combined Mission Assessment (NASA Data requirements) <ul style="list-style-type: none"> <li>SpaceX/NASA Delta CDR baseline and RID Closure Plans</li> <li>SpaceX assessment of SpaceX C2 Objectives and propose additional testing/risk mitigation events</li> <li>SpaceX proposed Combined mission profile and Consumables Assessment               <ul style="list-style-type: none"> <li>Identify key assumptions where actual data is not available</li> </ul> </li> </ul>	1/20	SpaceX Quarterly
NASA impacts/issues with C2/C3 Combine <ul style="list-style-type: none"> <li>NASA identification of additional risks , mitigation and changes required to Verification Plans</li> <li>Initial Proposed milestones/TIMs/Reviews required for ISS Integration Payment and C2/C3 Decision</li> </ul>	1/28	Telecom/Webex
SpaceX Combined Mission Assessment Delta (NASA Data requirements) <ul style="list-style-type: none"> <li>Presentation of current Design Drivers and Risks (Testing, analysis, critical path and major issues)</li> <li>Proposed changes to Verification plans and additional ground testing required for combined mission</li> <li>Updated Combined C2/C3 Mission Profile and Objectives and Performance Assessment (if changed)</li> </ul>	2/3	Telecom/Webex
Agreement on meetings/TIMs and data to be provided by SpaceX prior to April (Risk Mitigation) (Rolled into 75% ISS Integration Milestone )	2/8	Email/Telecom
SpaceX C1 Post Flight Review/Report	2/14	Document Delivery
CRS/C3PO/SpaceX C2/C3 Assessment/Mitigation Review <ul style="list-style-type: none"> <li>Review of proposed 75% ISS Integration Milestone and additional testing milestones</li> <li>Finalize COTS Cargo Augmentation milestones providing mitigation</li> </ul>	2/17	Email/Telecom
Internal ISS Combined Mission Presentation – Status of Work	2/24 & 3/1	TICB & SSPCB
ISS/C3P0/SpaceX Joint Review	3/2	Hawthorne, CA
*NASA C1 Post Flight Report Review/Assessment	3/24	JSC
*Completion of TIMs and TIM deliverables to finalize open Verification plans and vehicle baseline	4/14	TICB
*Completion 75% ISS Integration Requirements	5/21	TICB
HQ Combined Mission Decision Review	5/30	HQ



## Vehicle Baseline and Verification and Test Plan

---

- **October 2010, NASA/SpaceX conducted Vehicle Delta CDR and identified a number of open design issues and verification concerns.**
- **December 2010, NASA/SpaceX completed agreements on closure plans for all open RIDs**
- **NASA/SpaceX have reviewed the open verification plans and have developed plans to address finalizing the design baseline and joint agreements on all verification and test plans.**
  - Subsystem TIMs have been found to be the most effective means to come to agreement and close out issues with SpaceX.
  - Multiple TIMs are being held in Feb/March to address most of the open issues/RIDs and finalize verification and detailed test plans
    - COMM, Avionics, Software, Thermal, Struc and Mech, RPOC
    - **NOTE:** COMM and follow on RPOC TIM at risk to meet March deadline
- **NASA/SpaceX also assessing key technical areas C2 mission would have provided flight validation or risk mitigation. For identified areas additional testing or other mitigation is being identified and/or risk quantified.**



# Original Technical Areas Mitigated by C2 Mission

C2 Objective/Benefit	Current Mitigation Action
Additional Flight Test (Reduction in risk)	No mitigation available
Comm Link Validation Demonstrate full fault tolerant Avionics Transition to/from Prox Ops mode (Far field)	No additional mitigation planned.
RPOC Performance <ul style="list-style-type: none"> <li>• GNC Validation</li> <li>• Early RGPS Validation</li> <li>• Star Tracker</li> </ul>	<ul style="list-style-type: none"> <li>• LIDAR Testing – Open and Closed Loop testing at MSFC</li> <li>• SpaceX Javad GPS being compared with NASA Debris Radar (NDR) C1 over-flight pass tracking data.</li> <li>• DragonEye 2 also has a Javad GPS to compare with each of the 3 shuttle GPS position data and Best Estimate Trajectory.</li> </ul>
Integrated Thermal Analysis validation on C2	Additional Thermal Vac testing to be completed to validate integrated thermal control system and vehicle thermal performance.
Launch vehicle and on orbit performance of separation systems; <ul style="list-style-type: none"> <li>• 2<sup>nd</sup> Stage/Trunk Separation</li> <li>• Pontoon/Solar Array deployment</li> </ul>	Additional Ground Testing Review planned. Details in work with SpaceX.
SEE requirements validated on C2 <ul style="list-style-type: none"> <li>• New SpaceX plan to close out requirements for a combined mission is not clear and has not been agreed to by NASA. IRMA # 6264</li> </ul>	<p>Working through Radiation Environment Verification plan.</p> <ul style="list-style-type: none"> <li>• JPL/JSC/SpaceX team working through avionics box susceptibility.</li> <li>• Team also assessing redundant architecture and compliance to safety requirements.</li> </ul>



# Short Term Plan for Vehicle Baseline and Verification Plan Closures

System	open Delta CDR RIDs	Date	Issue	Mitigation	75% ISS Integration payment
POWER	5	Complete	Finalize Baseline Design	Joint review of battery design and build/test schedules	YES
		Complete	Verify Baseline Design meets Mission Performance requirements	Review of Solar Array performance assessments and assumptions	YES
		March 31		NASA Review of Battery and overall Power performance assessments and assumptions - Follow on TIM if required	YES
		April 1		AO/UA Solar Array degradation testing	YES
COMM	0	Complete	Finalize Baseline Design	Joint agreement for Short/Long Term Comm design/schedules	
		TBD	Finalize Verification Plan	Comm TIM to finalize design and verification plans	YES
Thermal/ECLSS	31	March 2-3	Finalize Baseline Design and Verification Plans	Thermal /ECLSS TIM to review final design changes/analysis and finalize verification and test plans	YES
		March 3	Verify Baseline Design meets Mission Qual/Performance requirements	SpaceX delivery of increased sub-component TVAC testing schedule and completions (Cargo Augmentation)	YES
		TBD		Additional TVAC testing and complete plan for subcomponent testing (Cargo Augmentation)	YES
Software	6	Feb 22 – 25	Finalize Baseline Design and Verification Plans	Software/Avionics TIM to finalize verification plans, required NASA documentation and test plans	YES
		March 22-23	Finalize Baseline Design	Delivery of S/W and FDIR documentation and Follow-On TIM	YES





# Short Term Plan for Vehicle Baseline and Verification/Test Plan Closures

System	# open RIDs	Date	Issue	Mitigation	75% ISS Integration payment
RPOC	22	Complete	Finalize Baseline Design and Verification Plans	RPOC TIM finalized verification plans and schedules for key verification events	YES
		April 15		Delivery of documents to support baseline/verification (RPOC TIM Protocol)	YES
		Mar – June	Verify Baseline Design meets Mission Qual/Performance requirements	Additional LIDAR Performance testing (Cargo Augmentation) <ul style="list-style-type: none"> <li>Open-loop and Closed loop testing (MSFC)</li> </ul>	YES
Safety	6	March 21 - 25	Finalize Baseline Design and Verification Plans	Safety TIM to finalize software assurance plan and conduct audit against Software Development Plan	YES
		May 30	Finalize Baseline Design and Verification Plans	Key milestones to support SRP related to baseline – such as Hazard Report and Phase 2 SRP Closure	YES
General	0	May 30	75% ISS Integration Requirement	65 (TBD)% VCN closures	YES
		May 30	75% ISS Integration Requirement	Key hardware builds and tests (Maintain Baseline schedule)	YES



## C2/C3 Combined Mission Profile

---

- January and April 2011 Joint Quarterlies, SpaceX presented a proposed combined Mission Profile
- Proposed Mission Profile combines the C2 and C3 objectives with minimal changes to the original mission plans and objectives
- SpaceX also provided a detailed consumables assessment showing positive margins. However, this assessment included a number of assumptions due to lack of actual performance data
  - Plan for NASA review of analysis – driving cases and key assumptions for power and prop



# Mission Profile Comparison

---

- **Standalone C2**
  - 10 km flyunder
  - Racetrack around ISS
  - 2.5 km flyunder
  - **Demo objectives**
    - AGPS, Abort, Commanding from ISS, RGPS, Free Drift
    - AGPS and Abort evaluated real time, others evaluated post mission
- **Standalone C3**
  - **Phasing directly to the Rbar initiated at 10km below ISS for berthing at N2 Nadir**
  - **Demo Objectives**
    - Retreat, Hold, LIDAR
    - All evaluated real time
- **Combined Mission**
  - **Only 2.5 km flyunder**
  - **Racetrack around ISS**
  - **Rendezvous and Berthing with ISS at N2 Nadir initiated at 10km below ISS**
    - Initiated at the same point as original 10km flyunder in standalone C2 mission and rendezvous in standalone C3 mission
  - **Demo objectives**
    - AGPS, Abort, Commanding from ISS, RGPS, Free Drift, Retreat, Hold, LIDAR
    - All objectives evaluated in real time
- **Similar to HTV/ATV strategy**



# C2/C3 Combined Mission Profile Assessment Plan

System	Date	Analysis Required
VIeR	March 31	NASA Review of Battery and overall Power performance assessments and assumptions - Follow on TIM if required
MOD	March 31	Ordering of Demo objectives based on new profile – ex. Free Drift demo will likely move earlier
	May 15	Time required to evaluate demonstrations – may drive change to the notional mission profile, specifically the time between the 2.5km flyunder and re-rendezvous with ISS for berthing. Currently no understanding of how long Dragon can loiter between flyunder and re-rendezvous, forward work to assess consumables after design (batteries, solar arrays, etc) is understood.
RPOC	Standard Open Work	Time sensitivity – Dragon will now berth several days later then during a standalone C3 mission, potential for systems to degrade over time
	Standard Open Work	Elimination of 10km flyunder – AGPS will be potentially be used closer to ISS, open work to evaluate
	Standard Open Work	Analysis for Re-rendezvous burns – understand specific burn profile for the racetrack, notional profile does not provide enough detail. If they differ significantly from current 10km flyunder followed by racetrack additional analysis will be required
PROP	March 31	NASA Review of overall Prop performance assessments and assumptions - Follow on TIM if required
Overall System	May 15	System Team assessment of vehicle baseline against new C2 C3 Combined mission profile



# C1 Post Flight Review

---

- **SpaceX provided full F-002 (C1) Post Flight report on Feb 14, 2011**
- **SpaceX provided NASA a post flight assessment of both the Dragon and launch vehicle performance during the flight.**
  - Overall description of anomalies was provided to NASA ISS, C3PO, MSFC CATS team, and Launch Services Program advisory teams.
  - Dragon assessment still in work. Identifying applicability of data gathered from C1 to the C2 C3 Mission and focus on those areas.
- **Overall mission was very successful.**
  - Issues related to ground infrastructure and hardware anomalies are in work and NASA is aware of all mitigations.



# Forward Work

---

1. Continue to track to Combined Mission Assessment Plan
  - Key TIMs, deliverables and analysis to support April combined mission decision
2. Continue to track to key milestones tagged to 75% ISS Integration Payment and Cargo Augmentation plan

**NOTE:** *Above items are dependent on SpaceX schedules and deliverables and could impact/slip planned April decision date*

3. Provide NASA assessment back to SSPCB, C3PO, and eventually HQ in late May to support combined decision.