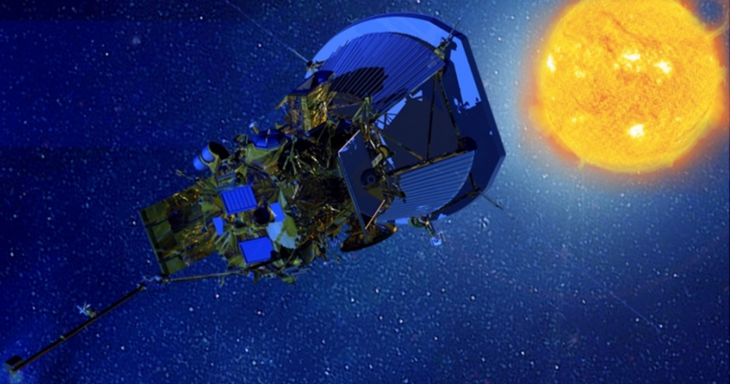
Solar Probe Plus

A NASA Mission to Touch the Sun



Launch Vehicle System

Steven Vernon
Launch Vehicle Integration Manager

steven.vernon@jhuapl.edu

13 – 16 January 2014

The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Agenda

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- **Launch Vehicle System Requirements**
- **Launch System Configuration and Performance**
- **Launch Sequence of Events**
- **Dual Launch Vehicle Compatibility**
- **Payload Interfaces**
- **Launch Services Acquisition**

Launch System Mission Requirements

- **Launch System Comprised of 2 highly Co-dependent Systems**
  - **A SPP Provided Upper Stage**
  - **A NASA Launch Services Program (NASA/LSP) provided Launch Vehicle (Note: SPP is a NASA Payload Class B, per NPR 8705.4)**
- **SPP Launch System Mission Requirements**
  - **The SPP Launch System shall:**
    - **Provide a SPP Spacecraft separated mass of no less than 665 kg. and a launch energy (C3) of 154 km^2/sec^2 as measured at the SC Separation event**
      - **Derived Requirement: Limit the SC propellant carried for injection accuracy “clean up” post separation to be no more than 60 meters/second**
      - **Derived Requirement: Maintain Dual Launch Vehicle compatibility until the Launch Vehicle is selected or NASA/HQ provides the SPP Project direction**

Launch System Configurations and Performance

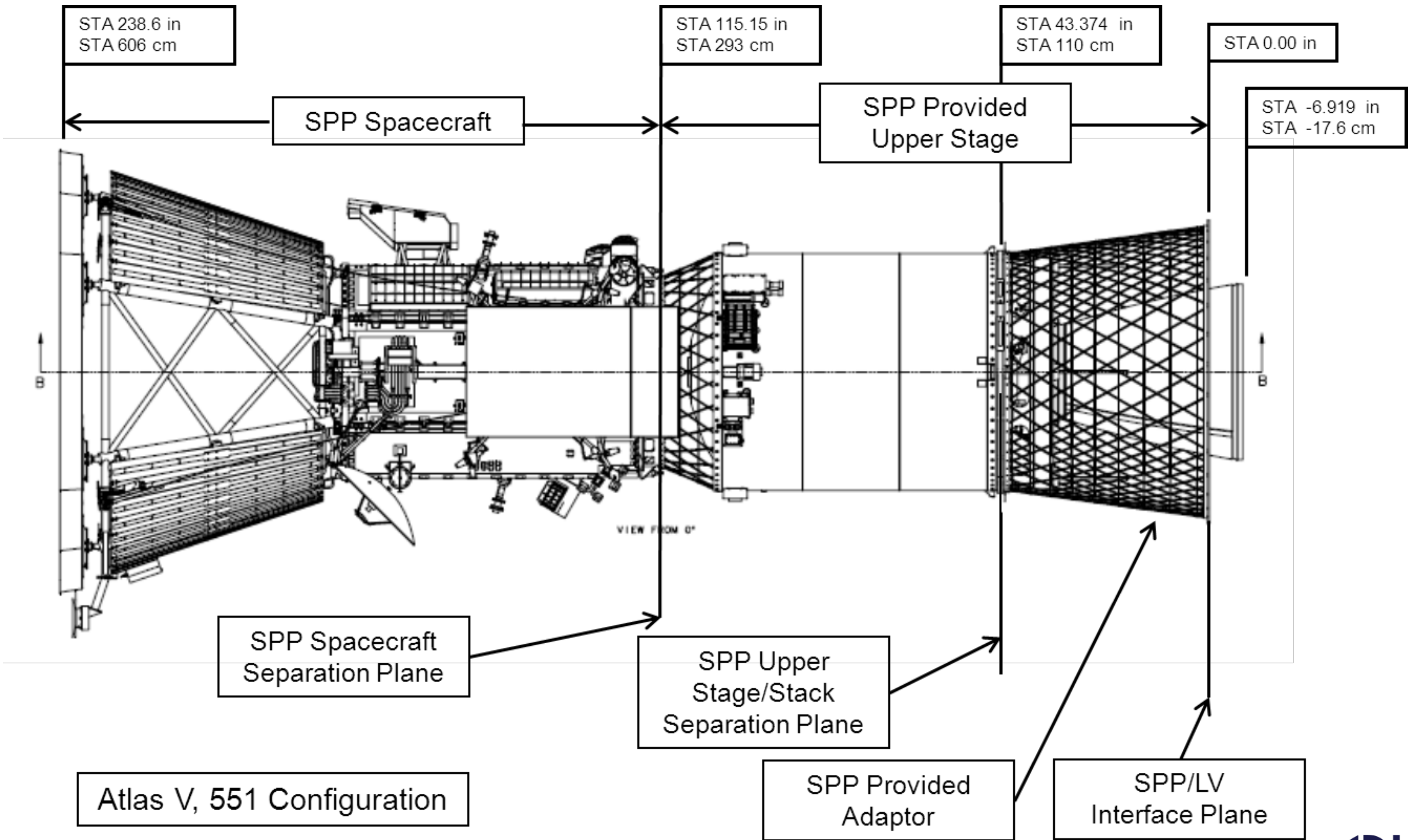
- **Atlas V, 551 and the STAR 48 GXV Upper Stage is the baseline configuration**
  - **2 Atlas performance enhancement studies completed (SPP/ULA/KSC)**
  - **Performance enhancements are required for Atlas to meet the mission requirements**
- **Delta IV Heavy and the STAR 48 BV Upper Stage**
  - **Is a lower risk alternative**
  - **Capable of meeting the launch energy mission requirements w/o performance enhancements**

Performance Enhanced Atlas V, 551 LV
STAR 48 GXV Upper Stage
- **Oct/13 Est. 665 Kg SC Separated Mass (max)**
- **Stage System design and motor development program In work**

Generic Delta IV Heavy LV
STAR 48 BV Upper Stage
- **Jan/13 Est. 760 Kg SC Separated Mass (prelim)**
- **Stage system design and FEM development in work**

Note: A Performance Estimate Summary Table is included in backup material
Both Launch Systems are included in the table

Launch System
Atlas V, 551 GXV Configuration



Launch Timeline Summary
Atlas V/GXV Sequence of Events

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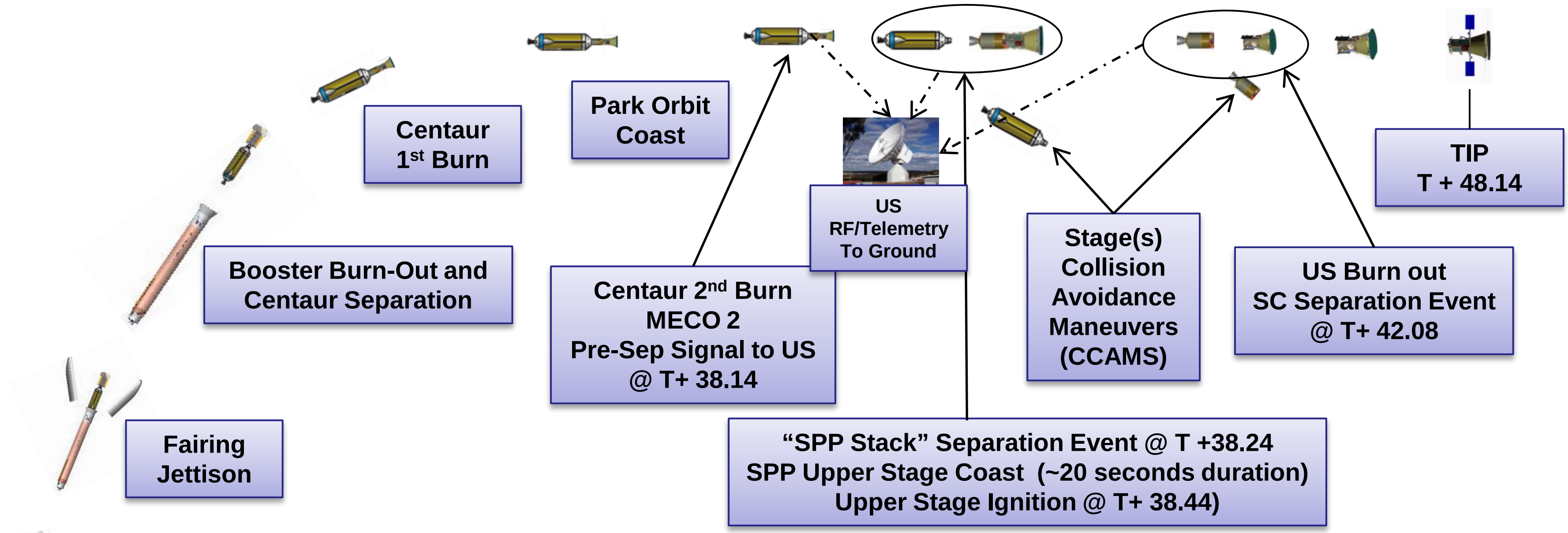

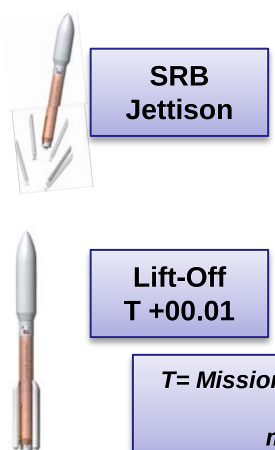

<u>Summary</u>
SC Switches to Internal Power @ T- 2 minutes
SC Separation @ 44 min, 8 sec (post internal power switch)
Target Interface Point (TIP) @ 50.14 (post internal power switch)

T= Mission Elapsed Time Units mm.ss

Note 1: Timeline depicted is consistent with a performance enhanced, Atlas V, 551 Trajectory, Upper Stage and NESC Analysis performed and co-variance matrices

Note 2: Launch system performance and trajectory analysis and requirements management are combined and managed across the mission via the NASA/KSC lead Mission Integration Process with the Launch Services Provider (similar to New Horizons)

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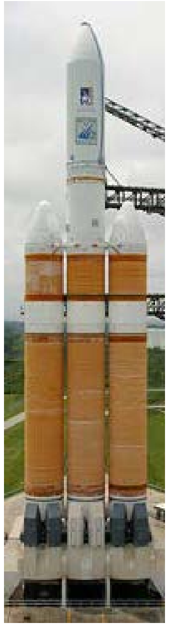
Dual Launch Vehicle Compatibility Achieved

Atlas V
200 ft.
Height

Delta IV Heavy vs. Atlas Compatibility Study					
#	Description	Atlas V 551	Atlas V 551 Info Source, Comments	Delta IV Heavy	Delta IV Info Sources, Comments
1	Mechanical Interfaces	Compatible	Planner's Guide	Compatible	Per Planners Guide
2	Electrical Interfaces	Compatible	Past Experience, PPG	Compatible	Per Planners Guide
3	Acoustics	Compatible	Past Experience, PPG	Compatible	Mission Specific Analysis Performed by ULA
4	Loads and Forces	Compatible	Coupled Loads Analysis Performed	Compatible	Compatible per Planners Guide
5	Physical Access	Compatible	Past Experience, PPG	Compatible	Per Planners Guide
6	Ground Processing	Compatible	Past Experience, PPG	Compatible	Similar +/- few days
7	Schedule of Deliverables and Data Products	Compatible	Past Experience, PPG	Compatible	Delta IV Heavy durations extended due to less automation vs. Atlas
8	Documentation, Verifications, etc.	Compatible	Past Experience, PPG	Compatible	Per Planners Guide
9	ICD Development Process	Compatible	Past Experience, PPG	Compatible	Per Planners Guide, ULA Processes
10	Injection Accuracy	Compatible	KSC/ULA Analysis	Compatible	KSC Analysis
11	Payload Processing Facility (ASO) Compatibility	Compatible	Past Experience, PPG	Compatible	Astrotech and ULA confirmed compatibility w/ASO for Delta IV Heavy processing



Delta IV
Heavy
225 ft
Height

The SPP payload is compatible with both candidate Launch Systems

Launch Vehicle
Dual Compatible Interfaces

- Mechanical
  - Standard Evolved Expendable Launch Vehicle Bolted Interface
- Electrical
  - Fixed, Standard Electrical Panel Interface (SEIP, non-separating)
- Communications
  - Upper Stage/LV 2-way, 1553 Communications Bus
- Purge
  - Standard Instrument Grade B Gaseous Nitrogen (GN2) Purge
- Flight Termination System (FTS)
  - Launch Vehicle designed and supplied, Range Safety Compliant
- Physical Access
  - Standard SC and Upper Stage post encapsulation requirements
- Contamination
  - Commensurate with a NASA contamination sensitive scientific mission

Launch Vehicle

Significant Events prior to PDR and Post PDR Proposed Acquisition Schedule

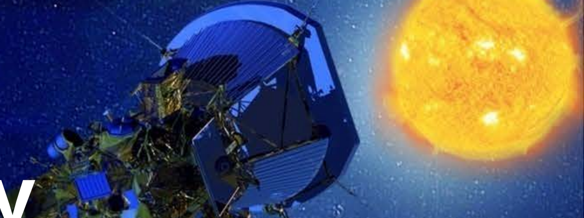
- **SPP Project is prepared to deliver a Launch Services and Interface Requirements Document to NASA for Launch Services Acquisition**

Nov/2012	Feb/2013	Summer/2013	Fall/2013	Jan/2014	March/2014	April/2014
ULA Advertises AF Block Buy Prices	*Congress Authorizes Negotiations*	*Block Buy 1A Released 7 Atlas, 3 Delta's 15/16 Cores Sold*	*POC Motor Firing*	*SPP PDR*	*Confirmation Review*	*IRD Released to KSC*

Fall/2014	Oct 2014	Nov/2014	March/2015
Proposed LV Contract Award Date	*LV K/O Meeting MIWG #1*	*Early Development Document (EDD/ICD) Started*	*SPP CDR*

Backup Material

Launch System
Performance Analysis Summary



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			Stage	Stage Parameters						Energy	SC	
Year/ Month	Source	LV	US Motor	SPP Stage Mass (Total, Kg)	Adaptor/ Sep System (Kg)	Burn Out Mass (kg)	Propellant Type	Isp	Propellant Mass kg	C3	SC Separated Mass (kg)	Comments
Sep-10	ULA Study	AV 551	STAR 48 GXV	2890	33	245	HMX	308.50	2612	158	610	
	KSC	Delta IV H (*2)	Pluto/NH	2260	122	245	TP-H-3340	294.20	2260	160	605	RS68-A Booster Engine
			STAR 48 GXV	2890	33	245	HMX	308.50	2612	160	770	
			STAR 48 BV	2197	33	154	TP-H-3340	292.10	2010	160	680	
Oct-12	ULA Study	AV 551	STAR 48 GXV	2890	33	245	HMX	308.50	2612	159	628	
Jan-13	KSC	Delta IV H (*2)	STAR 48 GXV	2890	33	245	HMX	308.50	2612	155	865	RS68-A Booster and US Propellant Change for GXV
			STAR 48 BV	2224	33	181	TP-H-3340	292.10	2010	155	760	
			STAR 48 GXV	3139	33	269	TP-H-3532A	308.40	2827	155	875	
Mar-13	KSC	AV 551 (*1)	STAR 48 GXV	2890	33	245	TP-H-3532A	308.50	2612	154	680	
			STAR 48 BV	2224	33	181	TP-H-3340	292.10	2010	154	650	
Jun-13	KSC	AV 551 (*1)	STAR 48 GXV	3168	46	270	TP-H-3532A	308.40	2852	154	675	
			STAR 48 BV	2245	46	189	TP-H-3340	292.10	2010	154	610	
Aug-13	KSC	AV 551 (*1)	STAR 48 GXV	3168	46	270	TP-H-3532A	Motor Ballistics	2852	154	673	MECO 2+20 Sec
	KSC			3168	46		TP-H-3532A				669	MECO 2 +40 Sec
Oct-13	KSC	AV 551 (*1)	STAR 48 GXV	3412	57	278	TP-H-3532A	308.40	3056	154	665	MECO 2 +40 Sec

Notes:

***1. Atlas IV, 551 performance estimates based on include medium and low risk enhancements identified in ULA Study and include planned fleet changes, etc.**

***2. Delta IV Heavy performance includes adaptor, smallest fairing, 2 mission unique doors, etc.**

Minimum STAR 48 BV Performance for Delta Heavy

Includes GXV Mass and Performance Margins and Atlas LV Enhancements

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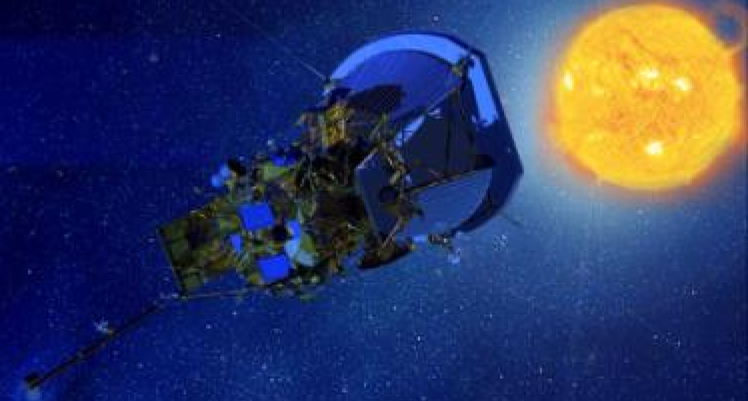

Upper Stage

Carl Engelbrecht — ***carl.engelbrecht@jhuapl.edu***

Richard Anderson — ***richard.c.anderson@jhuapl.edu***

Jeremy John — ***jeremy.john@jhuapl.edu***

13 – 16 January 2014

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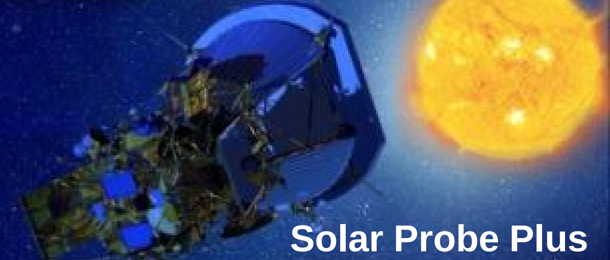
The Johns Hopkins University

APPLIED PHYSICS LABORATORY

Agenda



- Upper Stage Organization
- Upper Stage Overview and Schedule
- Review / Action Item Status
- Changes Since MDR
- Phase B Activities Overview and Context
- Driving Requirements
- Design Description
- Motor Development Plan
- POC Motor Test
- Development Status
- Project Status

APL SPP Launch System Team Organizational Chart

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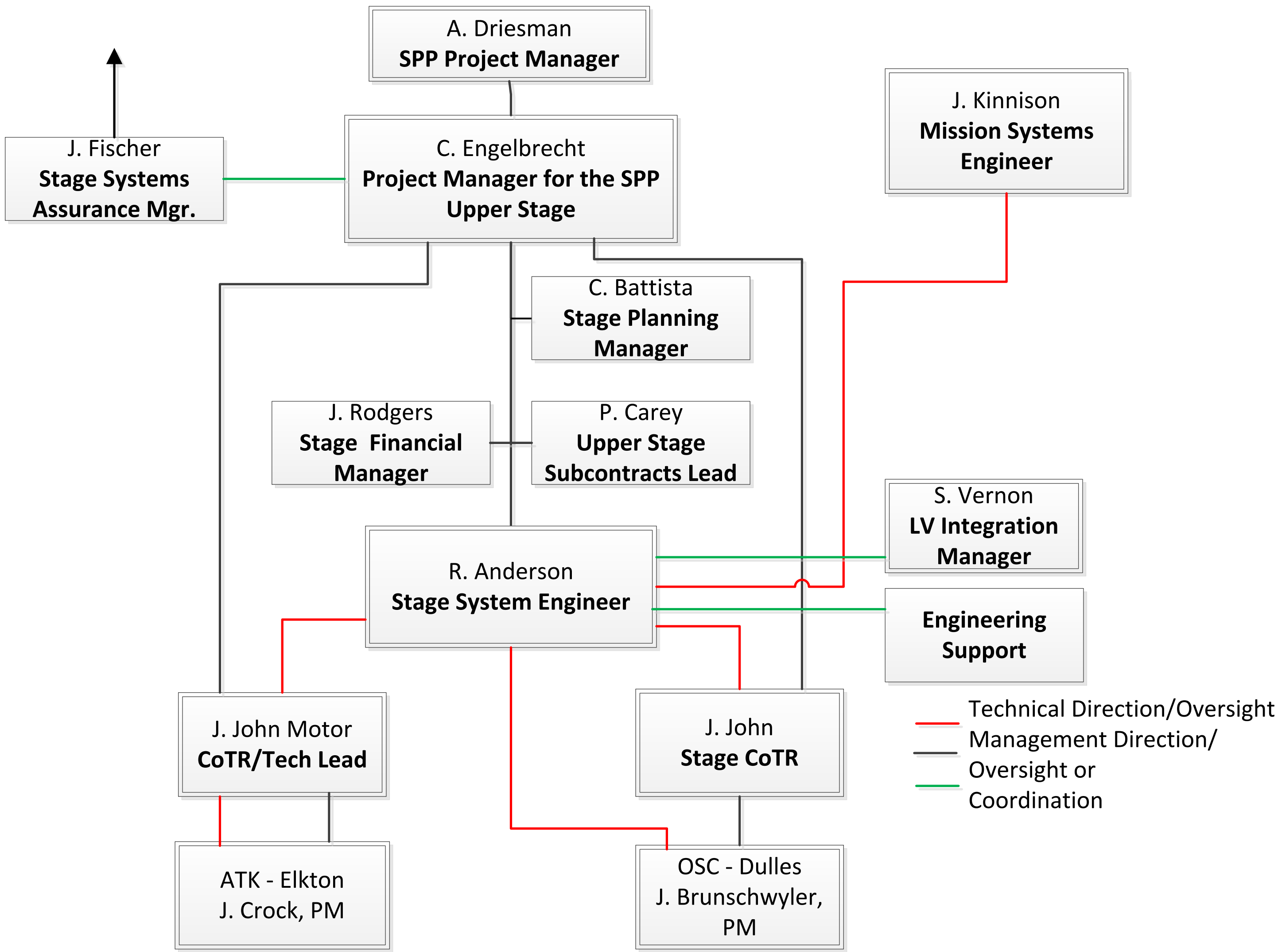

Upper Stage Overview

- **The Upper Stage project consists of two parts, the STAR 48GXV motor development and the stage development.**
  - **The motor is comprised of: propellant, insulated case, nozzle assembly, thrust vector control system, and the forward and aft motor skirts.**
    - **Development of the motor began at ATK Elkton in March 2012.**
  - **The stage is comprised of the avionics, telemetry, guidance, power, separation systems (both U/S-launch vehicle and U/S-spacecraft), the forward adaptor cone, and the payload separation ring.**
    - **Orbital Sciences Corp. (OSC) Dulles is the stage supplier for SPP**
      - **They are ultimately responsible for the entire stage design, which includes the integration of the motor into the stage.**
      - **Motor is provided to OSC by APL as Customer Furnished Equipment (CFE).**

Upper Stage System Configuration

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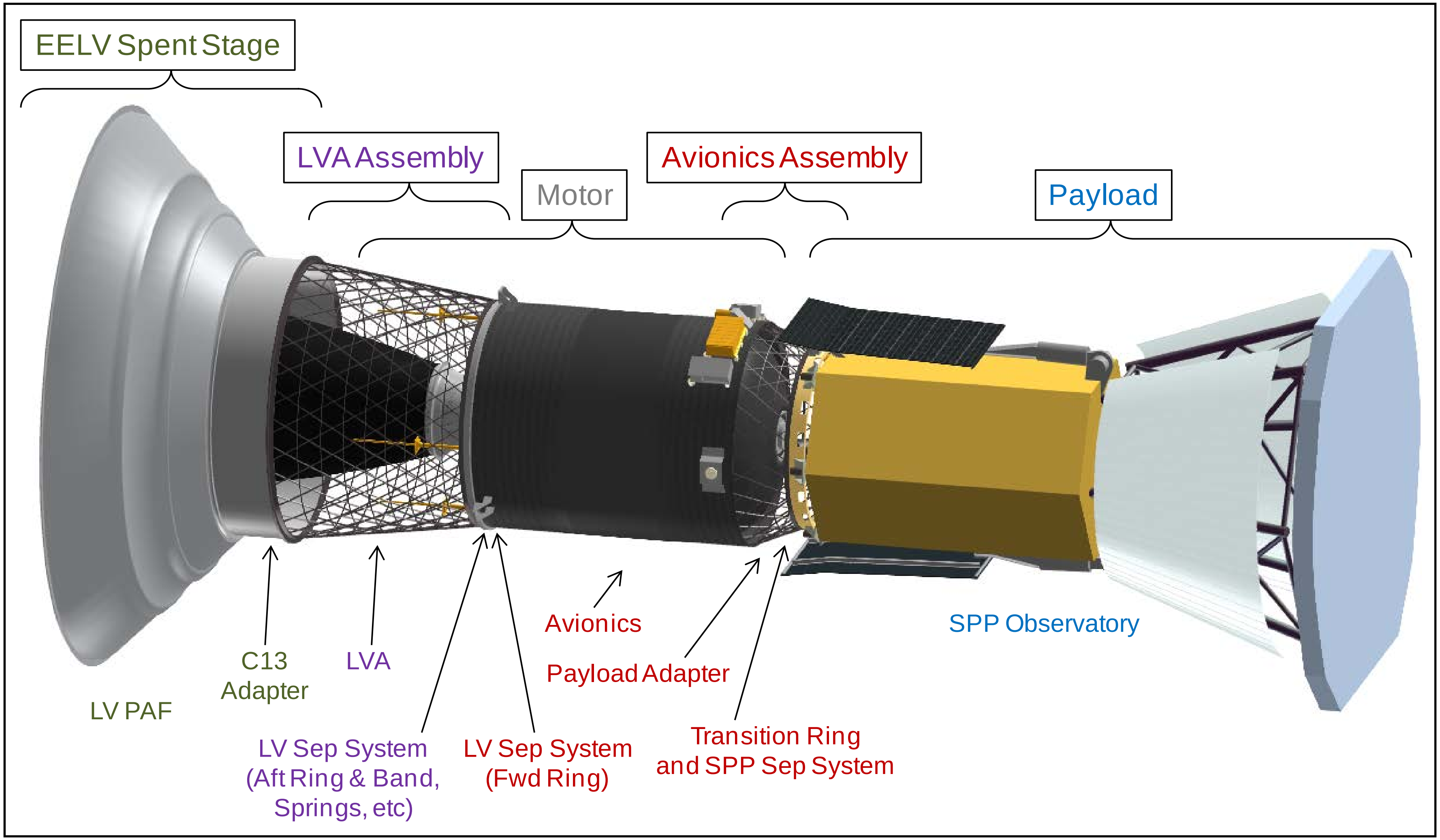

Upper Stage Schedule

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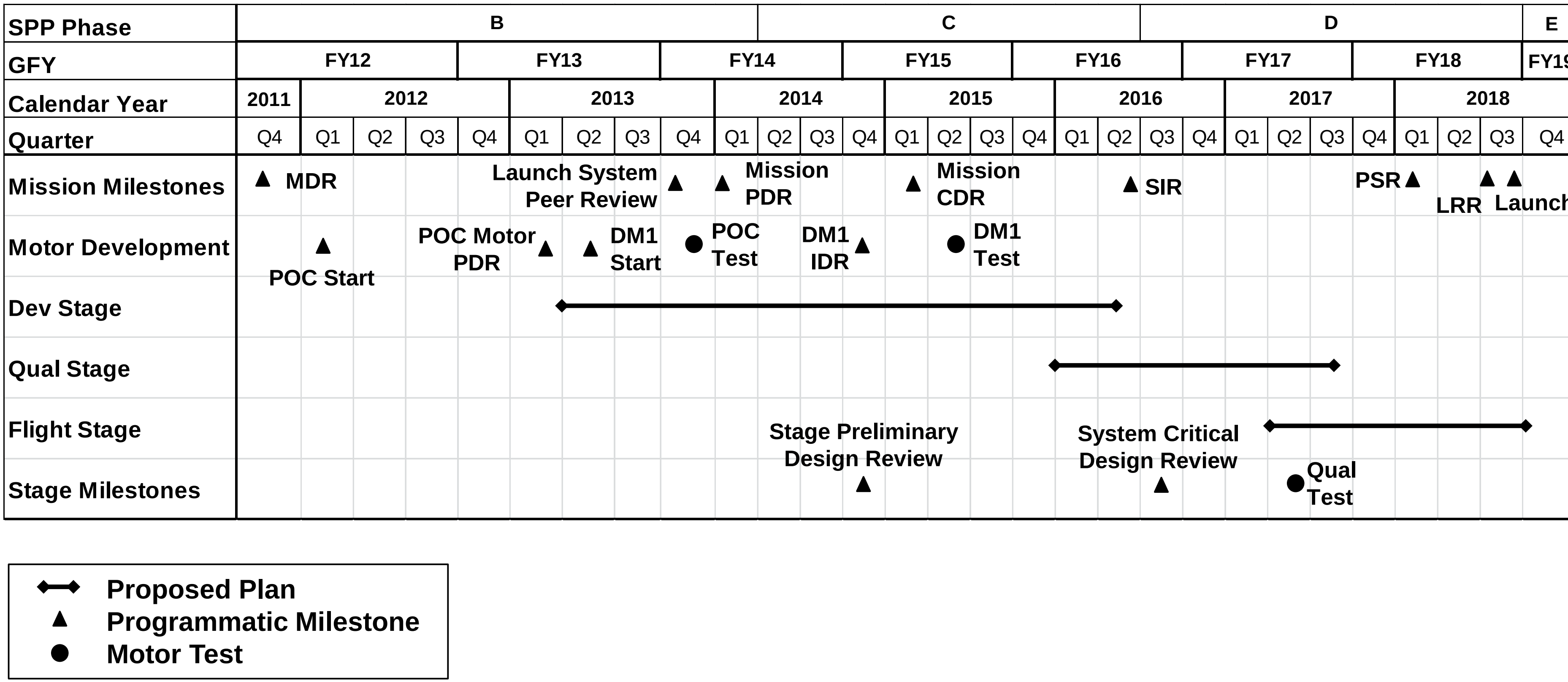

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Review / Action Item Status: Upper Stage System and POC Motor

- **Proof of Concept Motor PDR held on 13 March 2013:**
  - **Generated 14 action items and 3 advisories.**
  - **Responses for all of these have been prepared with 11 currently closed and the closure of the remainder pending completion of the post-firing analysis of the POC motor.**
  - **The advisories will be incorporated in the next design iteration.**
- **Launch System Peer Review held on 30 October 2013.**
  - **Objective: Demonstrate that the Launch System (including Upper Stage) is at a sufficient maturity level to support the SPP Mission PDR, in terms of providing a viable launch system solution and a path to proceed successfully to confirmation.**
  - **Generated four advisories and no action items.**
  - **The advisories will be incorporated into the next design iteration.**
- **Upper Stage PDR is scheduled for November 2014.**

Changes Since MDR

Change	Comment
Project Structure	The Upper Stage development was separated out as its own project within the SPP mission
Upper Stage System	Changed development plan to start stage development in Phase B rather than Phase C. Orbital added to team.
Development Motor Plan	Start of Development Motor effort also moved into Phase B.
Mission Design	Launch system requirement changed to deliver a separated S/C mass of 665 kg with a launch energy of 154 km^2/s^2.
Addition of ACS	Added a 3-axis, cold gas attitude control system as a result of trade study conducted by Orbital, and independent NESC study.
Motor Propellant	Changed formulation to reduce hazard rating.
Motor Case	Length increased to accommodate increased propellant load.
Nozzle Exit Cone	Material changed to C-C from carbon phenolic to reduce inert mass.
Ignition System	High voltage firing control for flight design to reduce inert mass.

Upper Stage System Engineering – Phase B Performance Analyses

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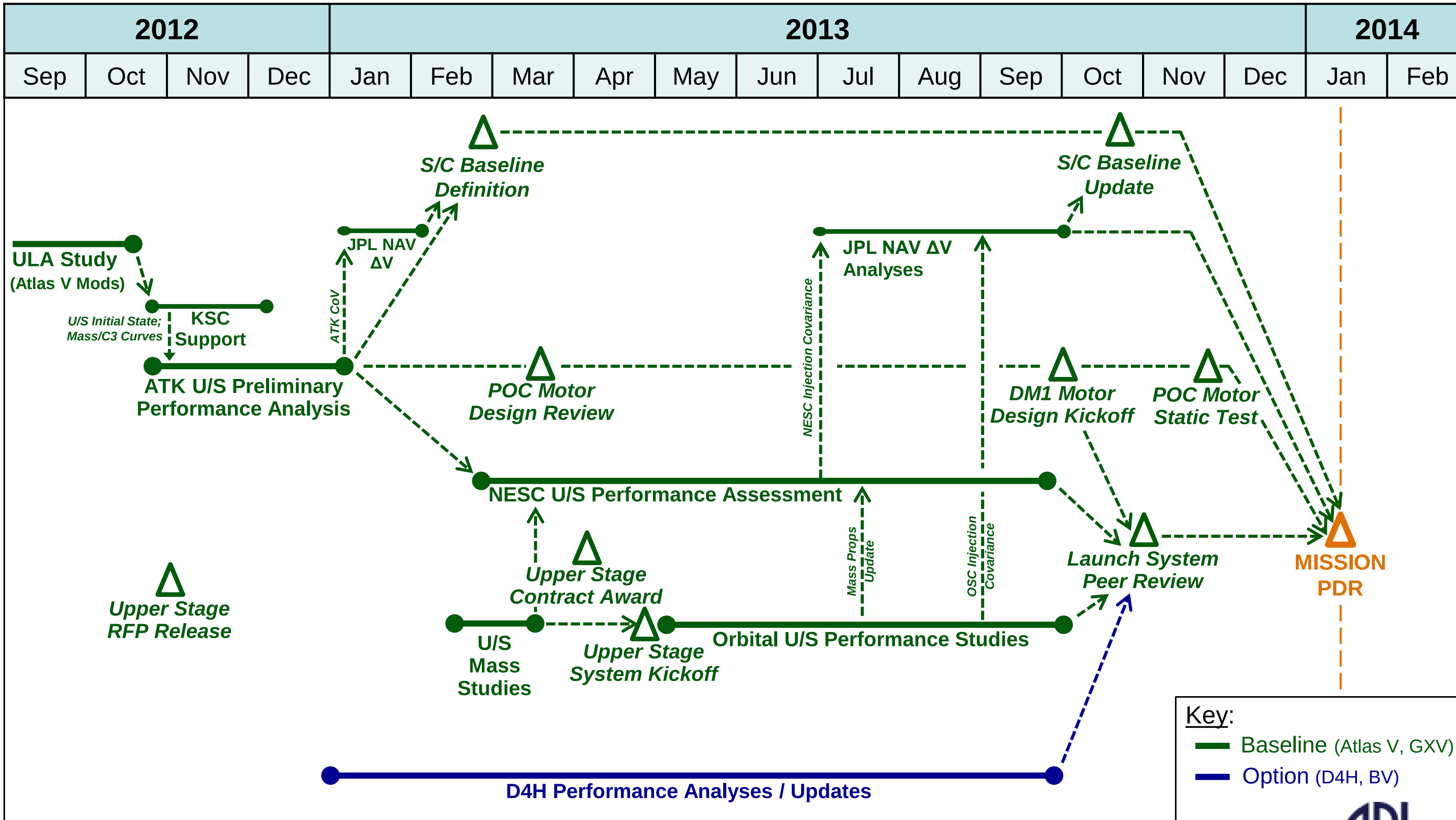

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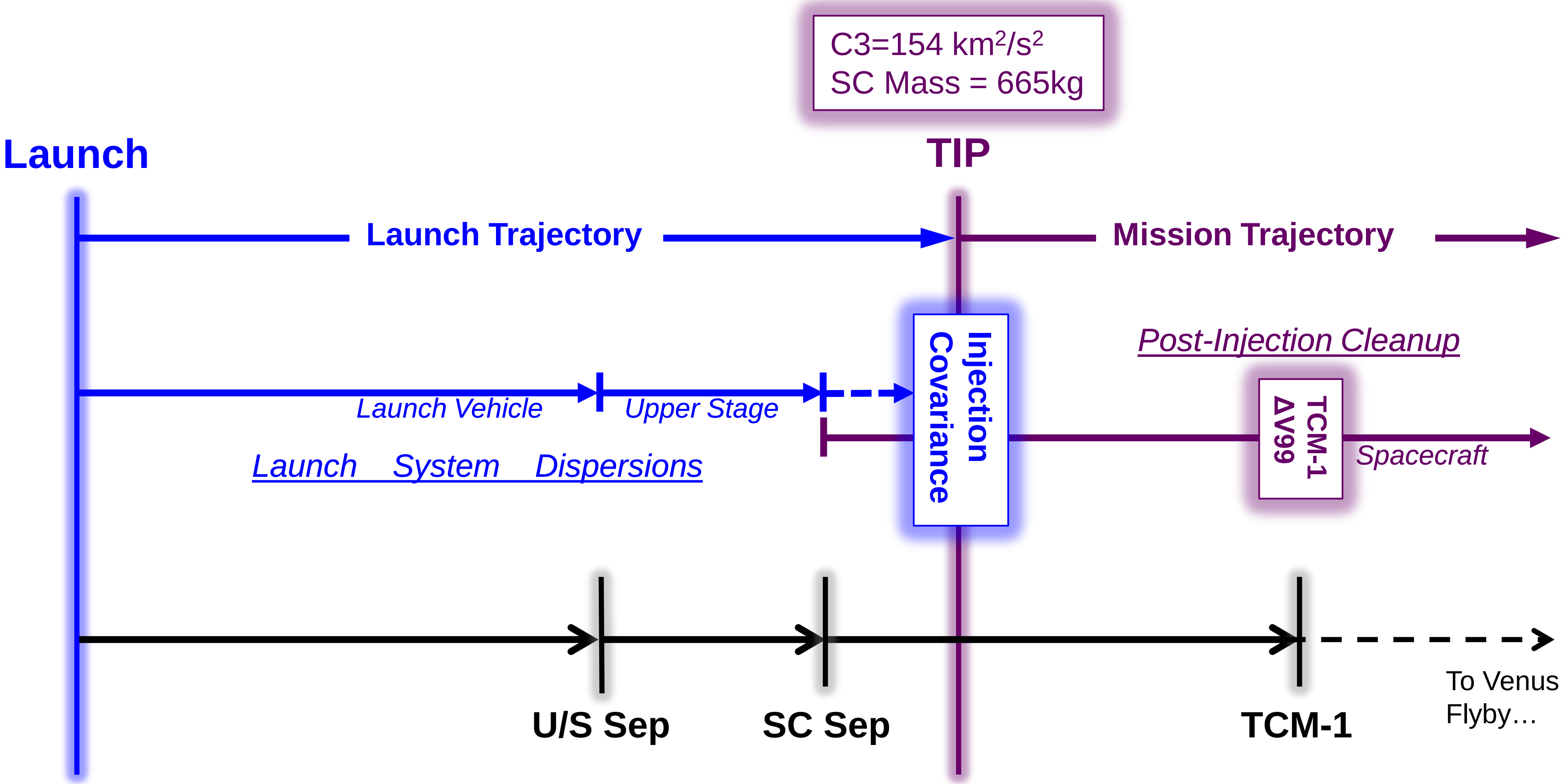
Key Performance Metric – Injection Covariance

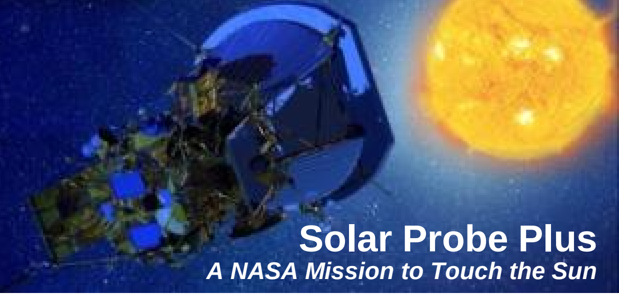


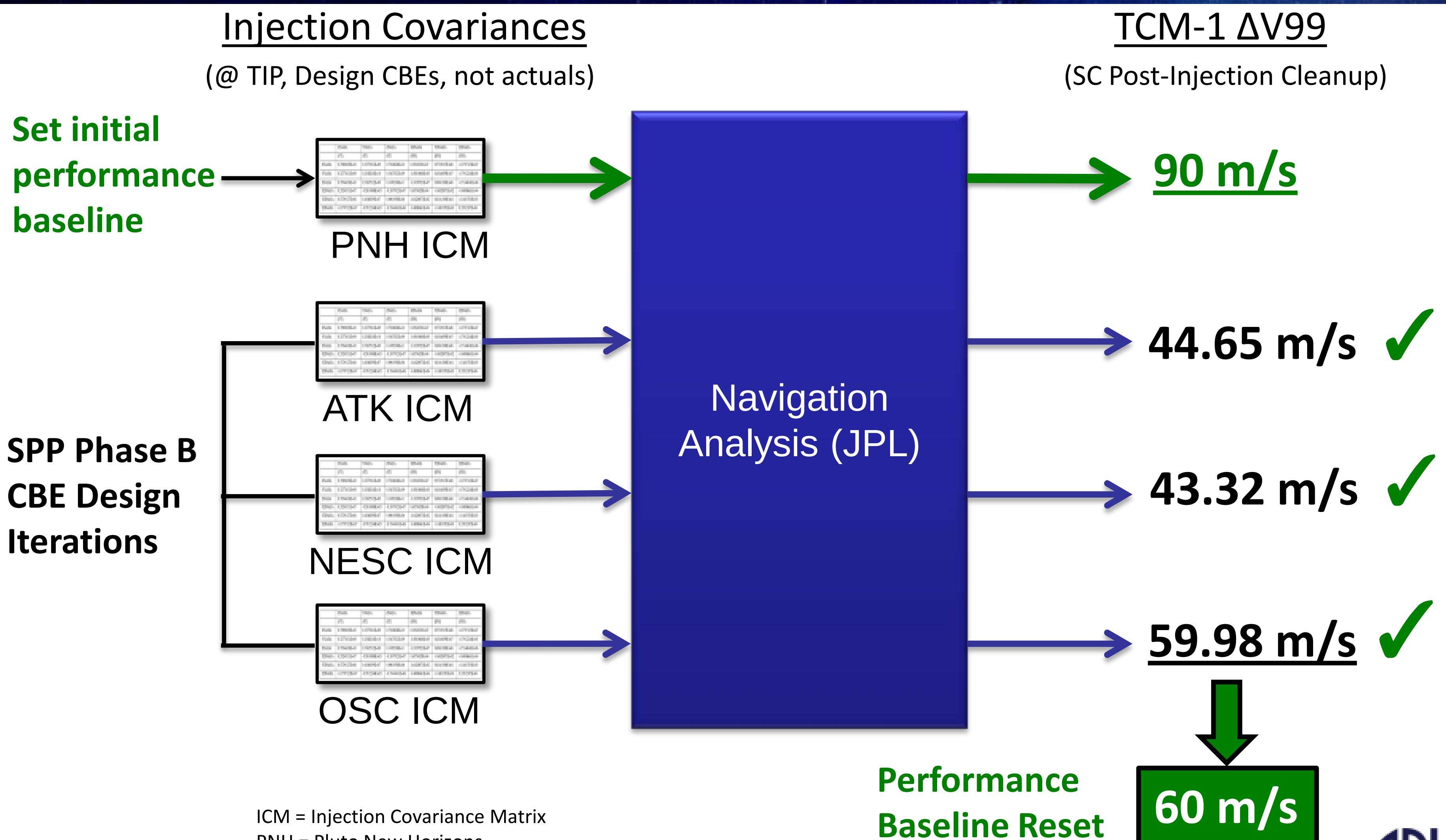
ICM: Injection Covariance Matrix

TCM: Trajectory Correction Maneuver

TIP: Target Interface Point

Injection Accuracy Validation Approach During Phase B





ICM = Injection Covariance Matrix
PNH = Pluto New Horizons

Upper Stage System – Driving Requirements

US-46	System Mass NTE	≤ 3412 kg (7523 lbm) [TBR]
US-43	Upper Stage Delta-V Magnitude	3.88 km/s [TBR] +/- [TBD] km/s, 3σ, assuming Observatory separated mass of 665 kg [TBR].
US-52US-76	Upper Stage Delta-V Direction Accuracy	RLA: 222.896 [TBR] deg +/- [TBD] deg DLA: -24.038 [TBR] deg +/- [TBD] deg At Target Interface Point (TIP), 3σ:
US-47	Upper Stage Motor Ignition Constraint	Achieve relative separation distance between the Upper Stage and the LV of at least 50 feet [TBR].
US-30	Operation in Radiation Environment (lower belt)	Peak proton flux: 1.2e3 protons/cm^2-sec [TBR]; Total fluence: 1.08e5 protons/cm^2 [TBR].
US-55	Observatory Post-Separated Body Rates	<= 2.0 deg/sec [TBR] in roll (about Obsv. Z axis); <= 0.5 deg/sec [TBR] in pitch (about Obsv. X axis); <= 0.5 deg/sec [TBR] in yaw (about Obsv. Y axis).
US-70	Post-Separation Relative Velocity	Relative separation velocity between Upper Stage System and Observatory ≥ 1.0 ft/sec [TBR].
US-32	Post-Separation Residual Plume Dir.	Motor exhaust direction ≥ 60 deg [TBR] from U/S body-relative velocity vector, from SC sep through U/S EOM.
US-26	Upper Stage Telemetry Downlink	Real-time Tx via RF of all U/S telemetry data, 10s [TBR] prior to LV sep. through 10s [TBR] after Observatory sep.

Upper Stage System Configuration – STAR 48GXV

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Avionics Assembly

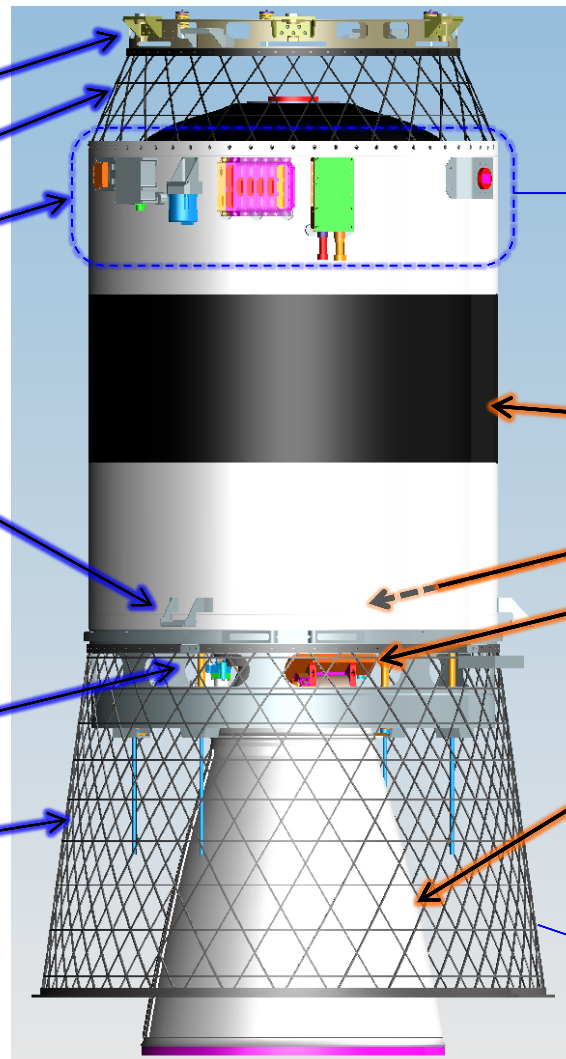
- SC Sep System / Transition Ring
- Payload Adapter
- Avionics Boxes
- LV Sep System (fwd portion)
- Cables

OSC

LV Adapter Assembly

- LV Sep System (aft portion)
- LV Adapter (LVA)
- Cables

OSC



S-Band Coupler & Terminator, Transmitter
1.5 Ah Battery
LN200 IMU
MACH
3 Ah Battery
S-Band Antenna (2X)

Motor Assembly

- Loaded Case
- Igniter
- Thrust Vector Control System
- Nozzle

ATK

Anisogrid Composite (“Lattice”) Structures: LVA and Payload Adapter

Upper Stage
Dry Mass Margins (GXV)

Item	Mass		Allocated Margin	
	CBE	NTE	Allocation	Pct.
Upper Stage Inerts	**327.70 kg 722.45 lbm**	**356.18 kg 785.25 lbm**	**28.49 kg 62.80 lbm**	**9%**
LVA Assembly	**50.01 kg 110.25 lbm**	**57.31 kg 126.34 lbm**	**7.30 kg 16.09 lbm**	**15%**
Avionics Assembly	**51.51 kg 113.57 lbm**	**58.11 kg 128.10 lbm**	**6.59 kg 14.54 lbm**	**13%**
			ACS	10%
			Payload Adapter	15%
			Avionics Boxes and Cables	19%
Motor Assembly – Inerts	**226.17 kg 498.63 lbm**	**240.77 kg 530.81 lbm**	**14.60 kg 32.18 lbm**	**7%**
			Exit Cone	15%
			Case insulation, Igniter Inerts, TVECS Battery, Ordnance	10%
			Case (except insulation) **[1]**	5%
			Nozzle Assembly (except Exit Cone) **[2]**	5%
			TVECS System (except Battery) **[3]**	3%

74% of Motor Dry Mass
50% of Stage Dry Mass →

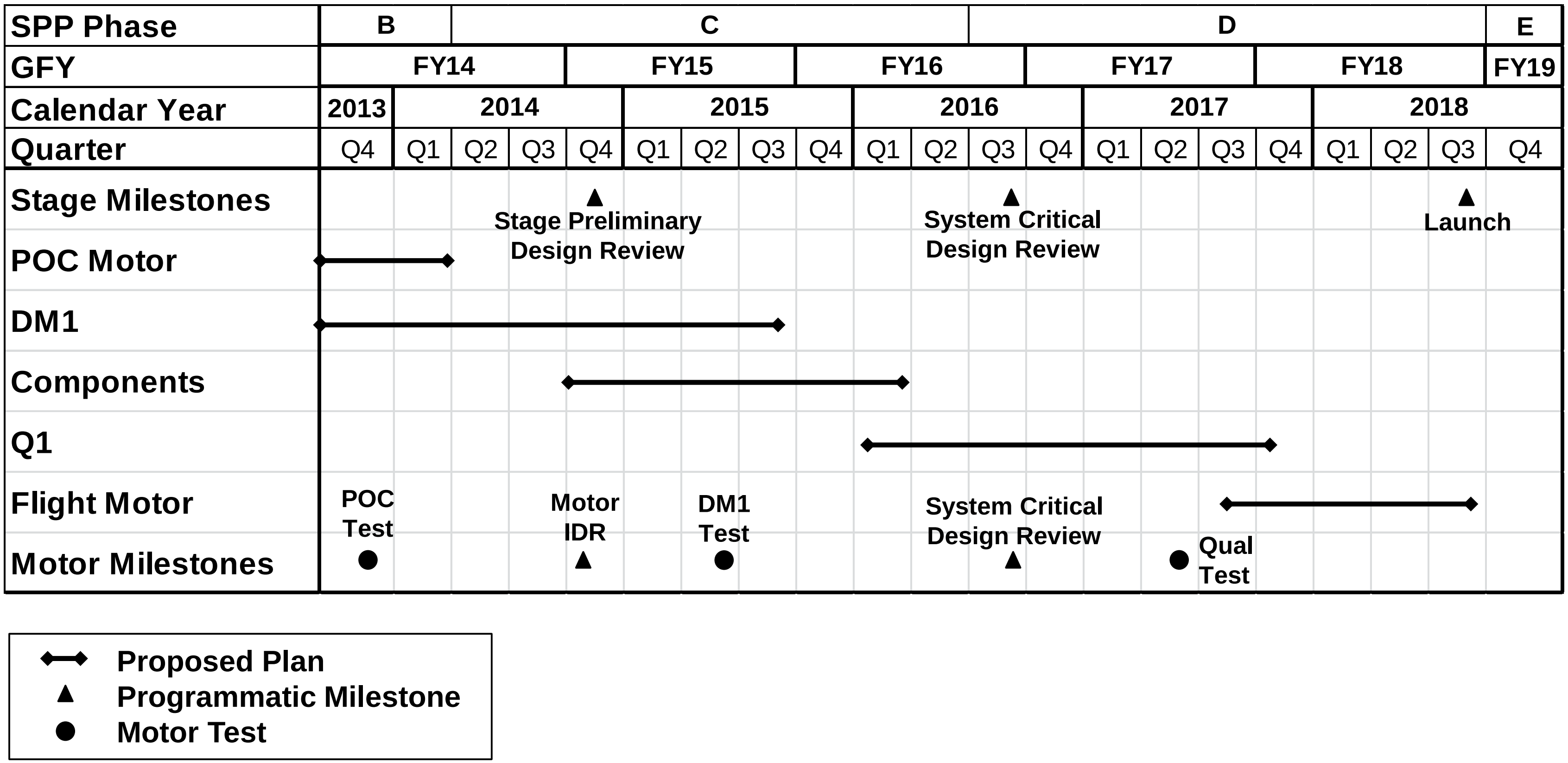
[1] Case manufacturer has demonstrated capability to meet required mass tolerances for POC.
[2] Nozzle Assembly component weights (except exit cone) verified by measurement for POC.
[3] TVECS components are built to print from as-flown design (Minotaur: TacSat-IV, LADEE).

Note: Extent of additional (unallocated) margin for stage use is TBD, pending POC Motor firing results and formal performance analyses by ULA after LV selection.

Upper Stage Power Margins

- **<u>Orbital Power Margin Analysis</u>:**
  (includes Orbital-supplied batteries and all Upper Stage loads except ATK thermal battery and TVECS actuator units)
  - **<u>30%</u> minimum margin per Orbital Requirement.**
  - **<u>126.9%</u> Best estimate prediction**
    - Based on as-measured performance of Minotaur components (TacSat-4 and LADEE missions)
  - **<u>77.9%</u> Worst-case prediction**
    - Based on SPP U/S component spec/data sheets.
- **<u>ATK Power Margin Analysis</u>:**
  (Thermal Battery and TVECS actuator units only)
  - **<u>>50%</u>**

Motor Development Plan



Motor Development Plan

- Original (pre-MDR) development plan was to follow the POC motor with a development motor (DM), a qualification stage, and the flight unit.
  - The purpose of including a DM is to incorporate lessons learned from POC motor to further mature and optimize motor design to be the “first iteration on the flight configuration”.
- After MDR, additional DM was added to bound performance at max temps and allow further mass and prop load optimization in qualification and flight motors.
  - Development motors then called DM1 and DM2.
  - DM1 effort started in Phase B, as early as possible.
    - This also led to the early start for the system integrator.
- Subsequently, motor-related cost growth necessitated the removal of DM2 from the development plan.
  - An appropriate project-level risk was assigned and is currently being track as part of the risk management process.

Motor Development Comparison

- **The SPP Motor development is comparable to other recent motor development projects at ATK that utilized a limited number of test motors prior to moving to a flight unit build.**
  - **NASA's Attitude Control Motor (ACM) for the Orion Crew Vehicle and MDA's Kinetic Energy Interceptor (KEI) utilized a comparable number of motors in the development effort.**

	Development Motors in Plan	Flight motors
STAR 48GXV	3	1
ACM	2	1
KEI*	5	2

*Only 3 motors tested and no flights were conducted prior to program's cancelation.

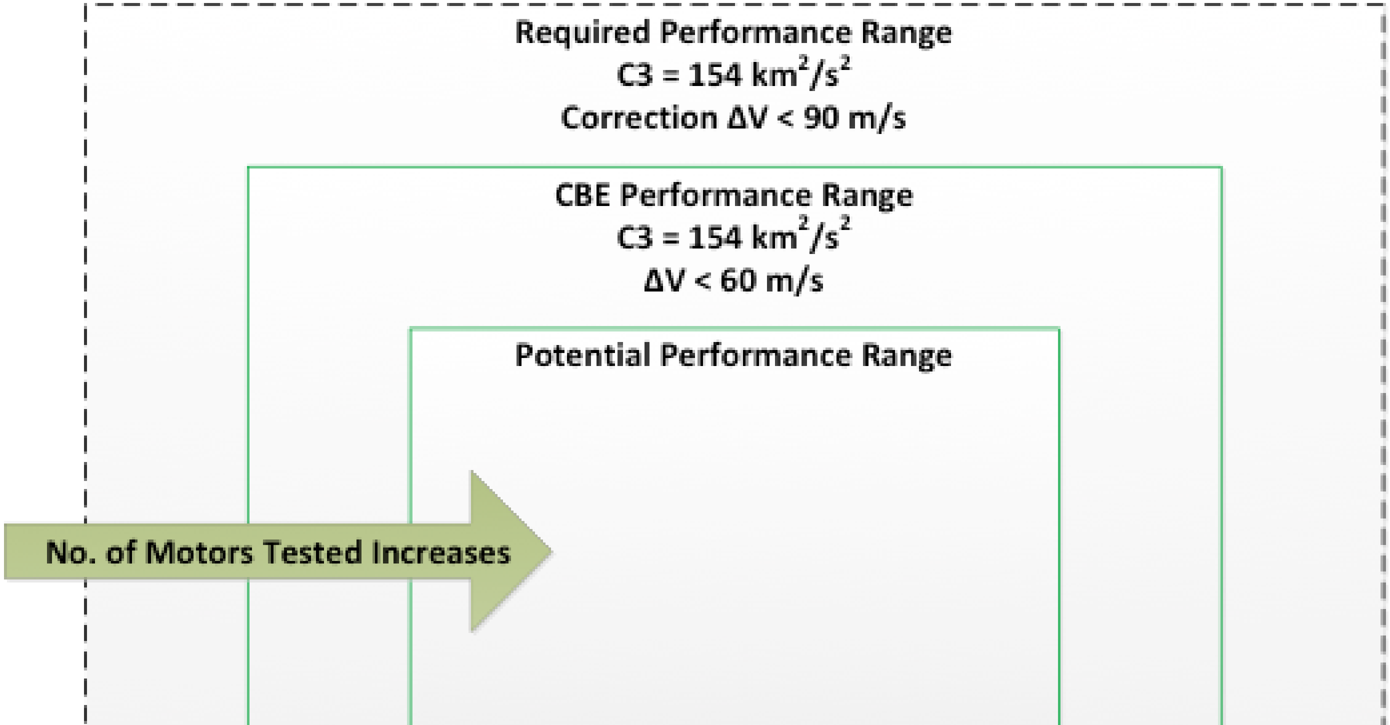
Motor Performance (1 of 3)

- **With the motors currently planned for testing, it will be possible to anchor the ballistic predictions from the proof-of-concept, then test at the operating temperature extremes with DM1 and the qualification unit.**
- **Following the completion of these tests, the ballistic parameters will be known to a sufficient level to reduce some of the uncertainty with the flight performance predictions.**
  - **The improved ballistic predictions only make the analysis of the launch system better in that it can narrow the dispersions used when assessing the launch system performance.**
  - **The predictions generated from the limited data will be sufficient to meet the mission requirements.**
- **The inclusion of a second development motor would have allowed for a further reduction in the performance uncertainty, but is not necessary as the motor can achieve the launch system performance requirements without it.**

Motor Performance (2 of 3)

- **Qualification of critical components further reduces the overall risk of the development and increases the confidence in the design.**
  - **Components such as the ignition system, nozzle assembly and TVECS are qualified prior to the full motor qualification test.**
  - **These tests are conducted in parallel to the DM1 activities.**
  - **Conducting these component qualifications also mitigates the elimination of DM2 by allowing another build cycle to be completed for the critical components.**

Motor Performance (3 of 3)



- **The CBE performance predictions indicate that the STAR 48GXV can generate the performance needed to meet the mission launch energy requirements with the current baseline development plan.**

POC Motor Test Video

Development Status

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FY12	FY13	FY14	FY15	FY16	FY17	FY18
- Upper Stage System Spec Development - Upper Stage System RFI	- Draft Upper Stage System RFP - Upper Stage System Procurement US System Concept Maturation - System Electronics Components (Avionics, Telemetry, Batteries, IMU)	- Mission PDR - System Component Design and Analysis (Fwd & Aft Adapter Rings, Separation System)	- Mission CDR - Development System Design Review (US PDR) - Draft Qualification Plan - Draft Acceptance Test Plan US System Development - System Electronics Testing	- System Component Tests - Development System Final Report - Flight System Design and Analysis - Flight System Design Review (US CDR) - Final Qualification Plan - Final Acceptance Test Plan	- Qualification System Manufacturing - Qualification Test Readiness Review - Qualification Environments Testing - Qualification Static Test (Altitude) - Qualification Report - Flight System MRR - Flight System Manufacturing	- Flight System Acceptance Testing - Flight System Delivery - Flight System Integration - Launch
- Motor Conceptual Design Trade Studies - Motor material procurements	- POC Motor Design and Analysis - POC Design Review - POC Motor Manufacturing	- POC Motor Static Test (Sea-Level) - POC Motor Final Report - Development Motor Design and Analysis	- Development Motor Manufacturing - Development Motor Static Test (Altitude)			

Project Status

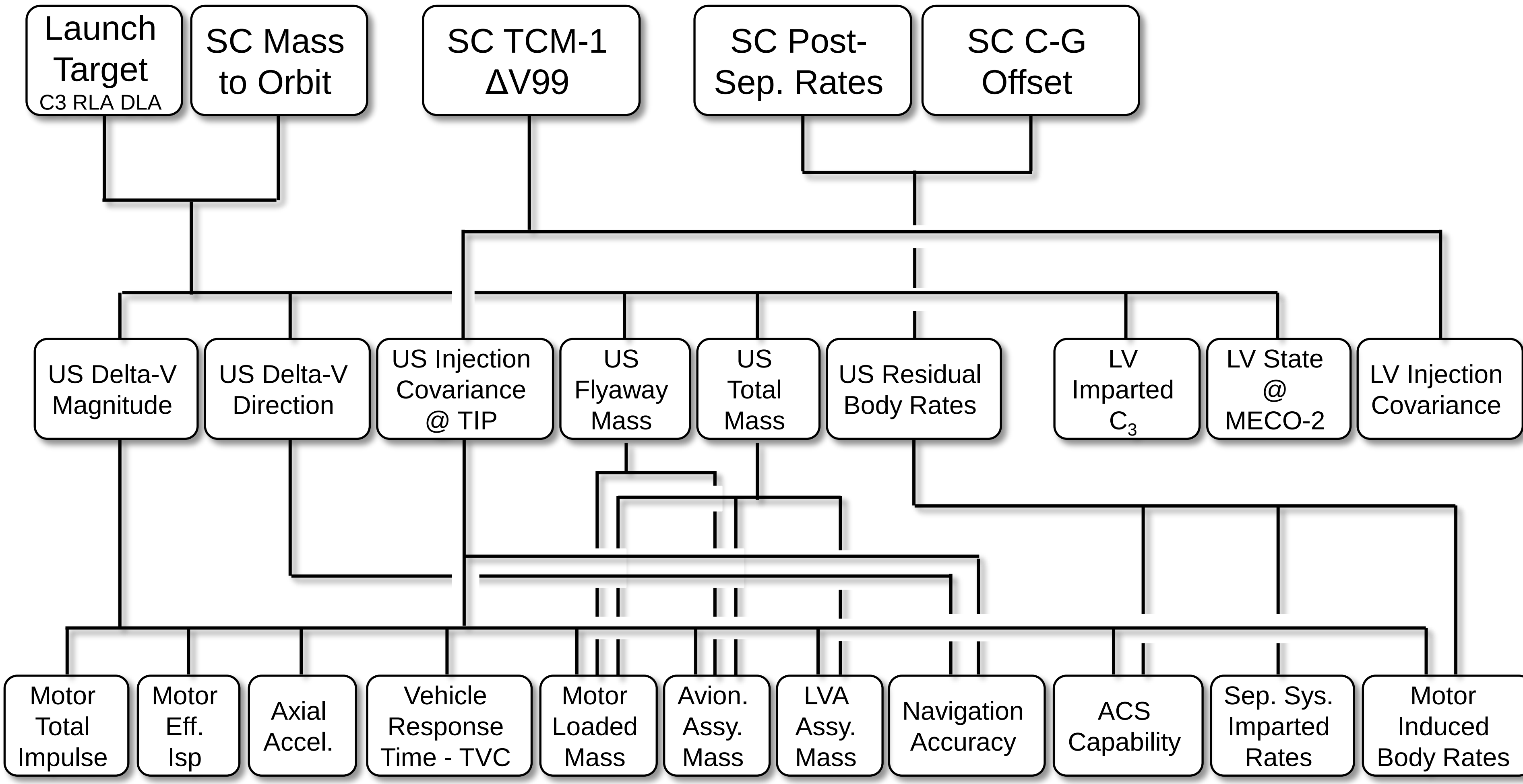
- **Upper stage efforts following plan**
  - **Proof of Concept (POC) motor successfully fired on December 5, 2013.**
    - **Post-firing analysis completed.**
  - **OSC on contract and stage design progressing as planned.**
  - **DM1 effort well underway.**
    - **Kick-off meeting held at ATK on Sept. 26, 2013.**
- **Upper Stage team is ready for Phase C.**

Backup

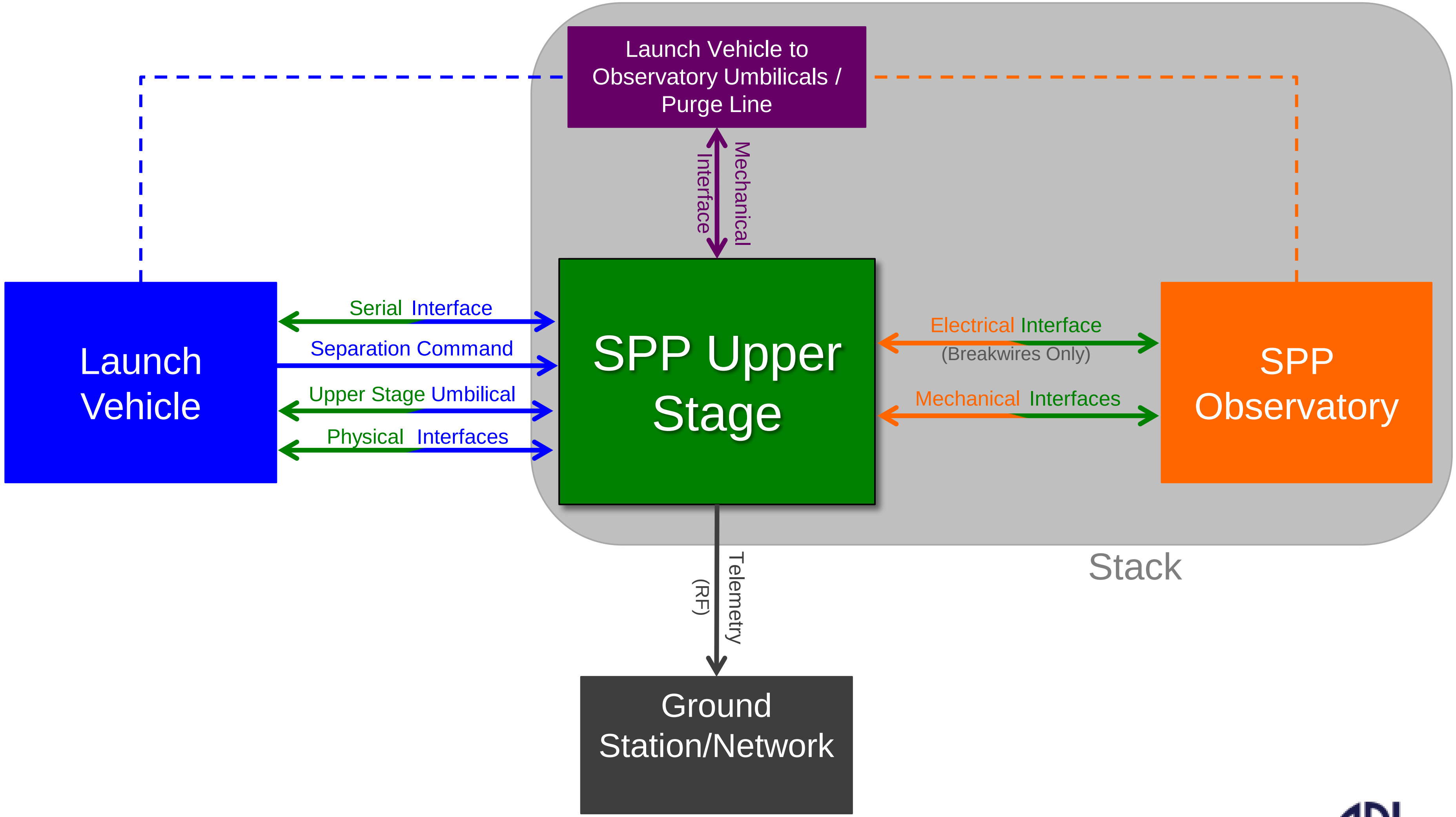
Upper Stage System – Phase B Documentation Deliverables Status

- **<u>SPP Level 3</u>:**
  - **SPP Upper Stage System Requirements:**
    - **Preliminary draft in progress, reviewed at OSC TIM#2**
    - **Requirements to be included in Upper Stage System Specification, to be developed in Phase C.**
  - **Upper Stage External ICDs in work:**
    - **Upper Stage to SPP Observatory ICD / MICD / EICD**
    - **Upper Stage to Ground ICD**
    - **(Contributions to) Launch Vehicle IRD / ICD**

Upper Stage Performance Requirements Flowdown Map



Upper Stage System – Mission Systems Context



Upper Stage System – Product Breakdown Structure

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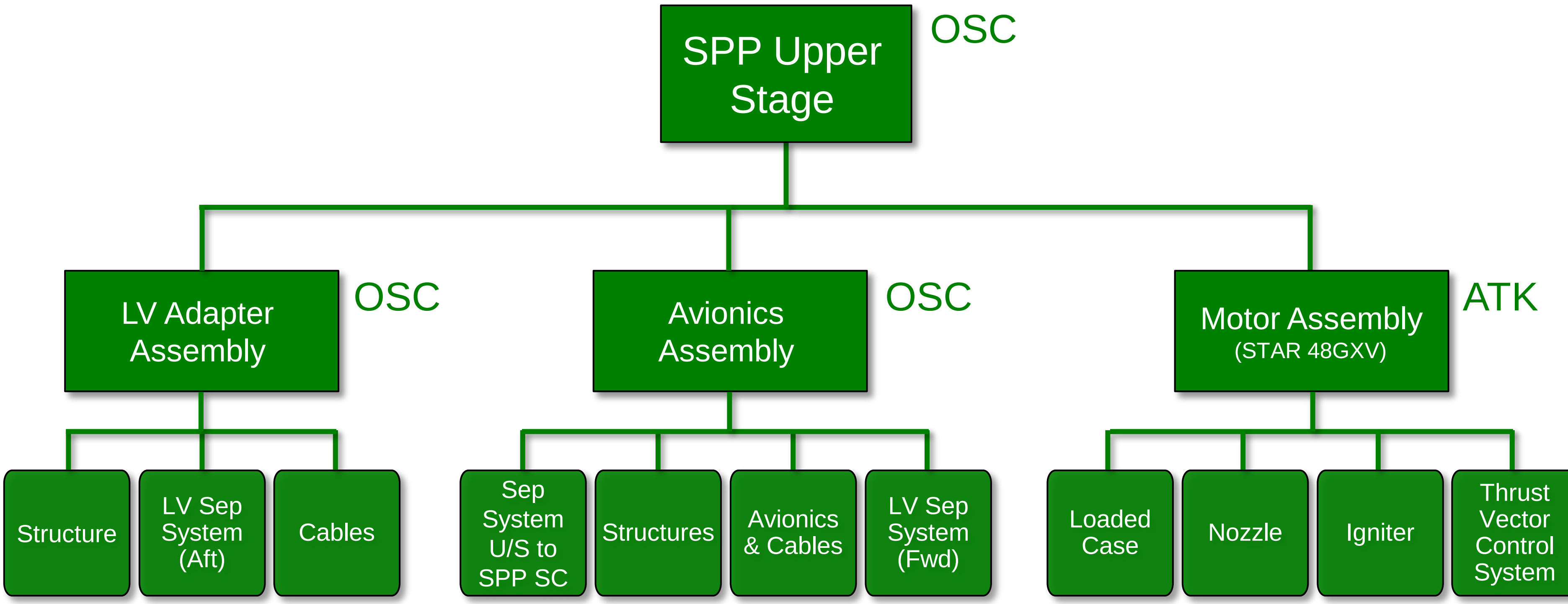

Upper Stage System – Interface Overview

➢ Upper Stage System External Interfaces:

- **Launch Vehicle**
  - Standard EELV bolted interface;
  - 3x non-separating, 61-pin connectors (2X for SC, 1X for U/S):
    - U/S Umbilical includes Telemetry/ Communications link to LV avionics;
  - Clamp Band Sep System (1X non-sep connector), Ordnance fired by LV;
  - Purge line connector (pass-through, LV-to-SC).
- **Observatory**
  - 6x Separation Bolts, Ordnance fired by Upper Stage;
  - 3x guided Spring Actuator Assemblies;
  - 2x Separating, 61-pin connectors (pass through for SC-LV & breakwires);
  - Purge line connector (pass-through, LV-to-SC).
- **Ground**
  - S-Band RF, Downlink Only (specific ground assets TBD).

➢ Upper Stage Internal Interfaces (Motor-Avionics, Motor-LVA):

- Details available in reference documentation.

Upper Stage System – Operational Timeline CBE

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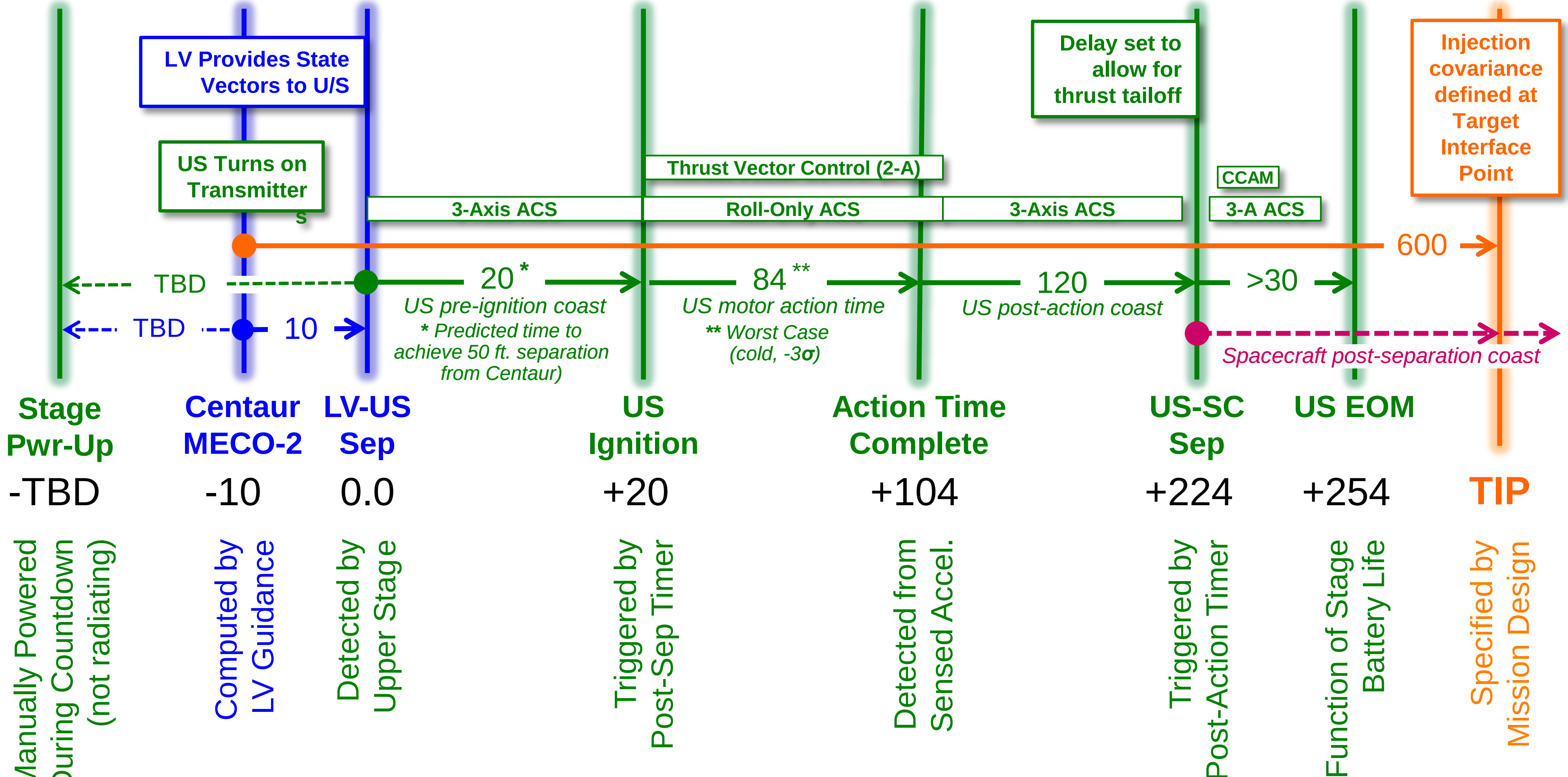

Key: Launch Vehicle Upper Stage
Spacecraft Mission

Note: ***All Units in Seconds***
Not drawn to scale – All numbers TBR

Upper Stage System – Summary of Key Phase B Trades

- **Attitude Control System (ACS) – CLOSED; Upper Stage will require an ACS to meet performance requirements.**

- **SC-LV Umbilical Routing (across U/S or via LV fairing) – CLOSED; Upper Stage is required to accommodate SC-LV umbilicals (x2).**

- **SC-LV Separation System (Retain Sep Nuts or use Clamp Band) – CLOSED; Separation Nut interface retained as most mass-efficient.**

- **U/S-LV Comm interface (RS-422 or 1553) – CLOSED; 1553 is standard EELV service. Use of RS-422 was identified as mass- and power- savings opportunity for Upper Stage, but 2-way RS-422 is not offered by the launch service.**

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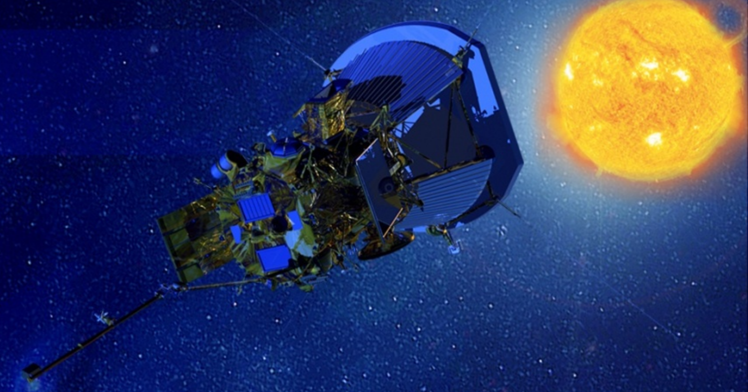

System Integration and Test

Annette Dolbow- I&T Lead Engineer
annette.dolbow@jhuapl.edu

13 – 16 January 2014

APL
The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Outline

- I&T Goals
- I&T Team Organization
- I&T Configurations/logistics
- Electrical GSE
- Mechanical GSE
- I&T Strategies (How we operate)
  - Working Docs ,CM and Anomaly Reporting
  - IRRs
  - Integration Procedures
  - Instrument Considerations
- System Level Testing
- Environmental Test
- Deployment Tests
- I&T Flow
- Work going forward

I&T Goals

- **Integrate each component to the Spacecraft in the safest most efficient way possible**
- **Test the system in as flight like a way as possible without taking undo risk with the hardware**
- **Deliver the fully assembled fully tested Observatory to the launch site at the appointed time**

I&T Team Organization

Engineers and Test conductors have lots of experience with I&T, but also, many of them are or will be working with SPP subsystem teams prior to rolling into I&T so they will bring knowledge with them about how the subsystems work

Integration and Test Lead
Annette Dolbow

Deputy Integration and Test Lead
Randy Schlotterbeck

Working and closely coordinating with systems and subsystem leads, in particular mechanical and thermal leads, SMA and CC as we move through I&T.

(Starting Jan. 2015)

Integration and Test Engineer

Integration and Test Engineer

Integration and Test Engineer

Integration and Test Engineer

Integration and Test Engineer

(Starting Jan. 2016)

Integration and Test Test Conductor

Integration and Test Test Conductor

Integration and Test Test Conductor

Integration and Test Test Conductor

Integration and Test Test Conductor

I&T EGSE Design Lead
Hien Ngyuen

I&T EGSE Design and Test
Jim Canoy

(Starting April. 2015)

Integration and Test Technician

(Starting April. 2016)

Integration and Test Technician

I&T Configurations and Logistics

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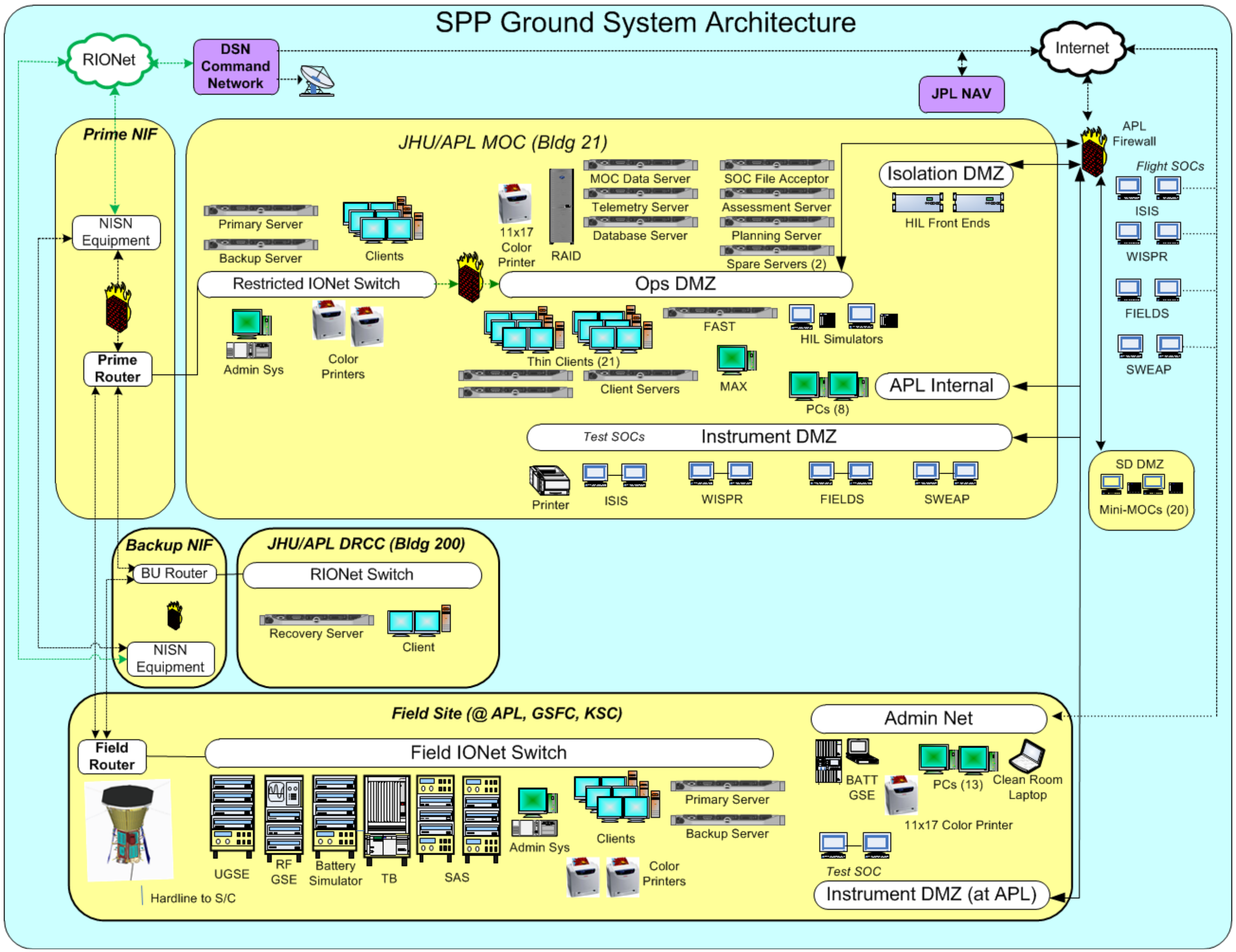
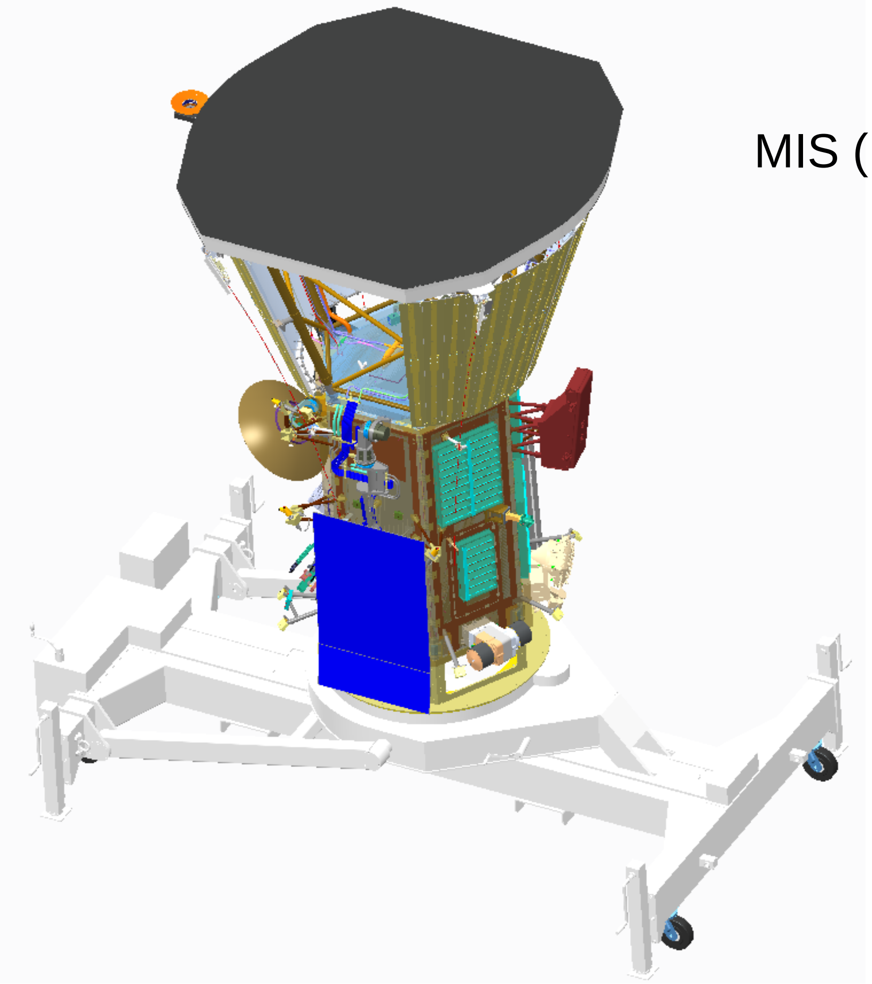


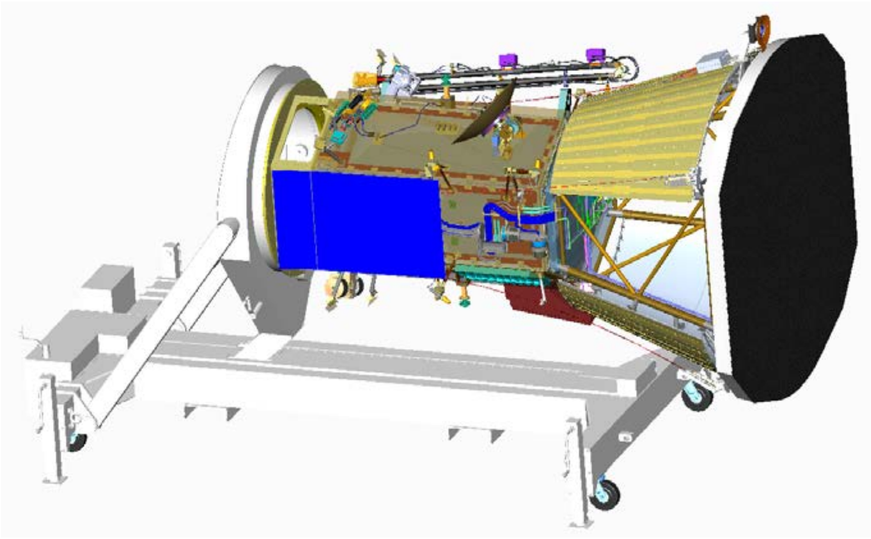
Electrical GSE

- **Umbilical GSE**
  - Power
  - Baseband Command and Telemetry
  - Actuator Circuit Monitoring and Simulating
  - Separation Simulation
  - Purge System Monitoring
  - Loss of Vacuum notification
- **RF GSE Racks**
  - Two racks, one in the clean room near S/C, One in the GSE room
- **Avionics Test Bed**
  - Test Port
  - Hardware Simulation
  - Telemetry Substitution
  - G&C Component Stimulation
  - Dynamics Model and G&C Simulation
  - Thruster Simulation and data capture
  - Observatory Timekeeping Test Support
- **Propulsion System Control Unit**
  - Operates Thrusters and Latch Valves While S/C is powered off
  - Controls Cooling System Latch Valves (TBD)
- **Propulsion System Monitor Unit**
  - Powers Pressure Transducers
  - Monitors Pressures
  - Monitors Temperatures
- **Actuator Verification Unit**
  - For Verification of Actuators in circuit
- **Solar Array Simulator**
- **Battery Test Rack**
- **Battery Simulator Rack**
- **Spacecraft Interface Simulator (SIS)**
  - Used to certify the UGSE

Mechanical GSE

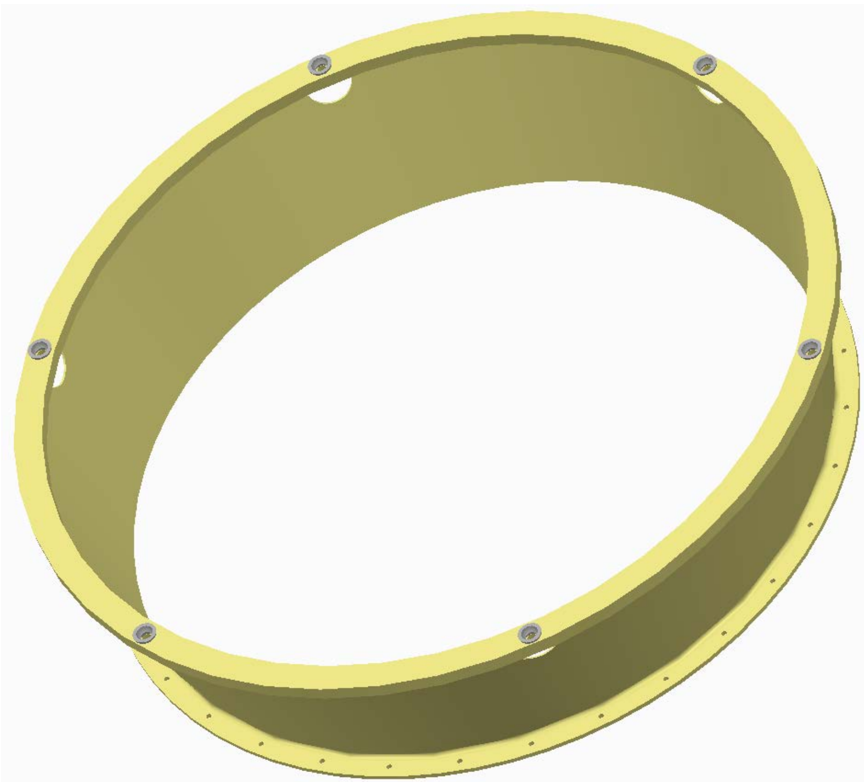


MIS (Multi-position Integration Stand

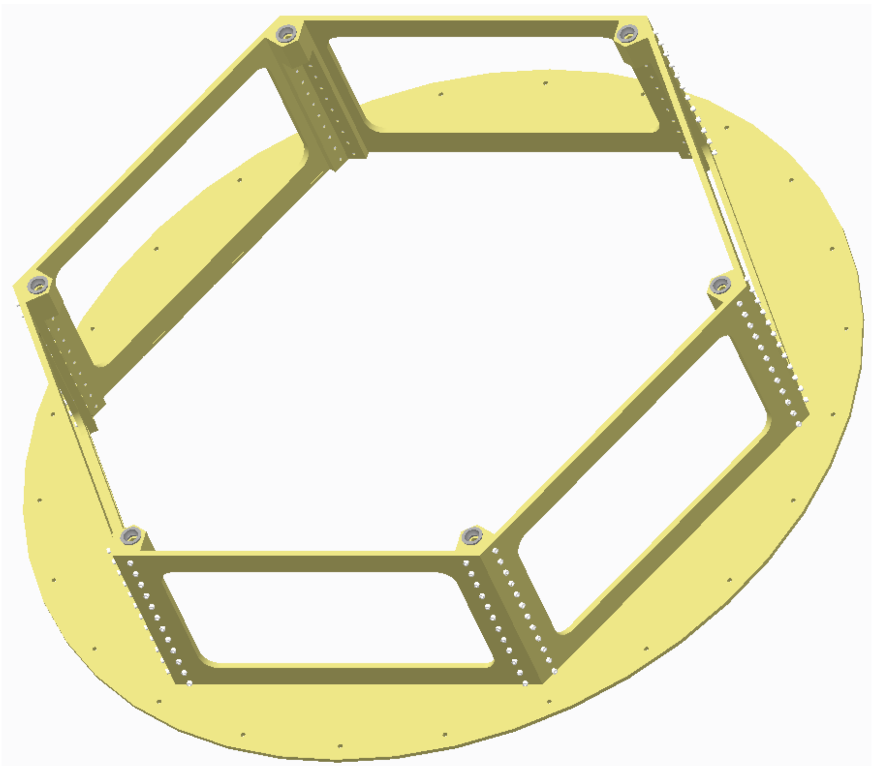


Mechanical GSE

Solar arrays hang below separation plane so an extension is necessary.
Also used to protect the precision mating surfaces of the separation system during integration.

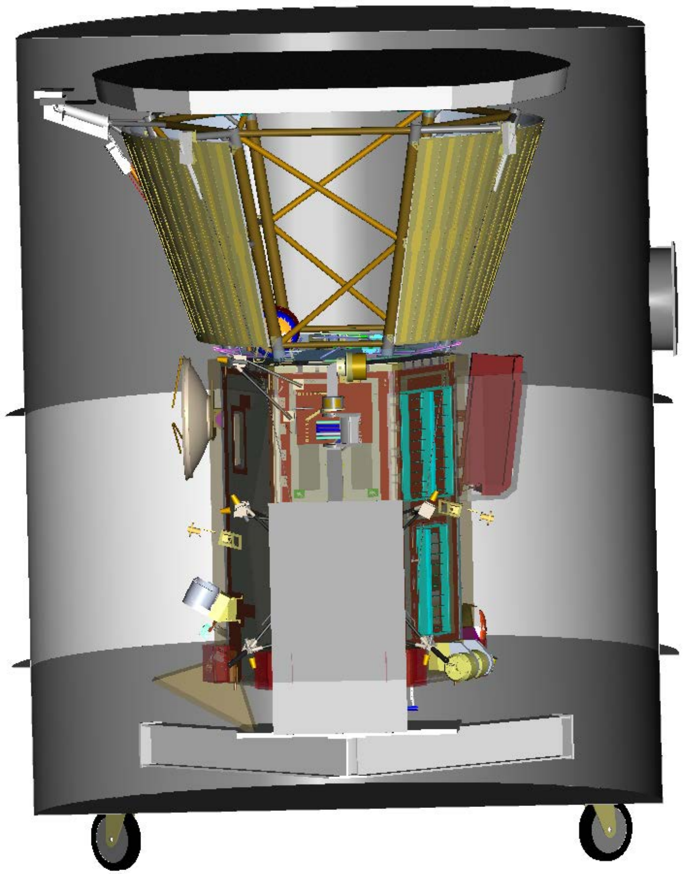


Ring forging based concept



Machined and bolted plate concept

Mechanical GSE- Shipping Container



- **Spacecraft not shipped with TPS or solar arrays installed but shown to demonstrate the container could be used as a safe haven for the hurricane plan at the cape.**

- **Modified Van Allen Probes Container**

Additional Mechanical GSE

- **Lift Fixture**
- **Panel Supports**
- **Various GSE Hinges and Brackets to support I&T and Testing**
- **Dollies for moving the S/C around**
- **Elephant Stands if needed**
- **More will be revealed….**

I&T Strategies- Docs, CM and ARs

- **Plans**
  - Logistics Plan, System Integration and Test Plan, Environmental Test Plan, etc.
- **Procedures**
  - All Component Integrations
  - Many System Level Tests
- **Work Orders**
  - Written to go along with procedures as well as for troubleshooting and testing that does not need a full blown procedure
- **Scripts**
  - L3 automated tests run from the console

- **Configuration Managed**
  - PLM for
    Plans and Procedures
  - Work Orders logged and maintained in Davis Drive I&T Folders
  - Scripts managed using SVN

- **Anomaly Tracking and Resolution**
  - APFR data base
  - All issues, small or large get written up
  - Weekly meetings with systems, SAM, I&T and others as necessary to investigate and resolve issues

I&T Strategies- IRRs

Integration Readiness Reviews held a day to a few days prior to integration on the S/C

- Subsystem Information and Documentation
  - Bakeout verification
  - Mass
  - Outstanding thermal or structural models
  - Copies available of As-Run test data for acceptance test and box level environmental testing
  - Mate/Demate counts for all connectors
  - Operating times: total and failure free
  - Waivers & Liens
  - List of constraints:
    - Contamination
    - Limited life items
    - Operating constraints (including limits)
    - Handling constraints
    - Safety issues
  - Configuration drawings
  - Red Tag/ Green Tag Spreadsheet
- I&T Team Readiness
  - Connector Pin-out Verification
  - Command and Telemetry Database
  - Signed off Integration Procedure
  - Signed off Installation Procedure
  - All JAS Scripts and Page Displays ready
- Hardware:
  - Connector dust covers
  - Red tag items
  - Green tag items
  - Ground straps (if not provided by APL)
  - Thermal isolation hardware (if not provided by APL)
  - Thermal Blankets
  - Optical Cubes installed, if needed
  - Test cables
  - Electrical GSE (ie. Stimulators)
  - Mechanical GSE
  - Any mechanical brackets not provided by APL
  - Test actuators, if needed
  - Shipping container or travel tote

I&T Strategies- Procedure

- Incoming Inspection (QA)
- Visual Inspection (I&T)
  - Connector Labeling
  - Connector Inspections
  - Flatness
  - Box Imperfections
- Bench Checks
  - Passive Measurements looking into the box
  - Connector to chassis bonding measurements
- Magnetic Sniff (EME)
- Mechanical Installation (ME)
  - Record in Installation Log
  - Box to S/C Bonding Measurement
  - Ground Straps installed if needed
- Safe-to-Mate (Breakout Boxes)
  - Passive into the harness
  - Passive into the box
  - Voltage at the harness to verify proper pins
- Interface Checks (BOBs)
  - Loaded Voltage (line balance)
  - Signal Characterizations
  - In-rush Measurements
- EMC testing (EME) (BOBs)
- Functional Testing (BOBs)
  - Verify all commands
  - Verify all telemetry
- Performance Testing (if any)
  - BOBs removed
- EMC testing (EME)(NoBOBs)

I&T Strategies- Instruments

- Each instrument team will be responsible for developing their Aliveness, Functional, and Performance test procedures
  - **Aliveness – 15 minutes each instrument**
  - **Functional – 1-2 hours each instrument**
  - **Performance – 4-6 hours each instrument**
- The S/C Test Conductors will control all power switching (On/Off/Enable) of the instruments
- Instrument team will then perform all commanding of their instrument
- Instrument Teams will perform evaluation of the instrument performance

System Level Testing

- Aliveness Tests- in btw vibe axis and acoustics runs, post shipment or move, Aliveness Plus on Pad
  - Verifies that the components and instruments can be powered, receive commands, provide telemetry
  - 3-5 hours in duration
- Functional Tests- pre and post Tvac, pre and post Vibration, etc…
  - Verifies all power and data paths to and from components and instruments, but not necessarily all permutations of functionality for those paths
  - Endeavors to test all command functions and exercise all telemetry
  - In general, the test will exercise as much functionality as possible without requiring external stimulus and GSE reconfiguration
  - 10-16 hours in duration
- Performance Tests- post integration, hot and cold in TV, ASO
  - A detailed verification that the components and instruments meet performance specification requirements
  - 5-7 days in duration

System Level Testing

- **4-5 Mission Simulations**
- **G and C Phasing Tests**
- **End- to-End Tests**
- **Autonomy Testing**
- **Fault Protection Testing**
- **Solar Array Safe mode testing**
- **Timekeeping Tests**
- **RF Compatibility Tests**
- **Plugs out Test (happens during EMC test period)**
- **Mag Swing Test (TBR)**
- **High/Low Voltage testing**
- **Thermal System Phasing Test (Heaters and Temp Sensors)**
- **High Rate/Low Rate data flow testing**

Environmental Test

- EMI/EMC
  - APL Bldg 23 EMI Tent
- Vibration Testing
  - APL Bldg 23 Vib Lab
- Shock Testing
  - APL Bldg 23 Vib Lab
- Acoustics Testing
  - GSFC
- Thermal Balance Testing
  - GFSC
- Thermal Cycling
  - GFSC

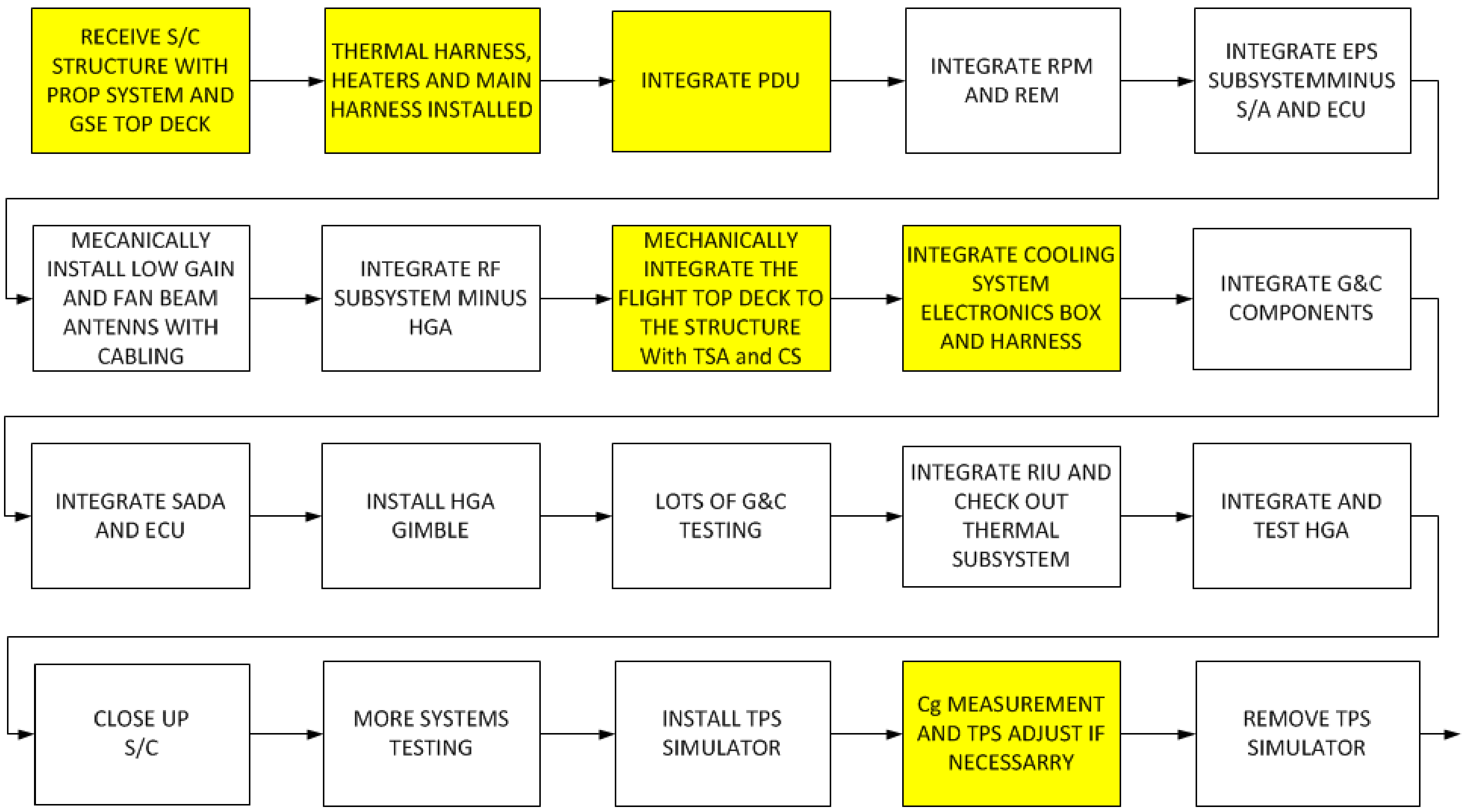
- I&T Command Workstations and GSE Racks
  - Moved to SSL for Vib and Shock
  - Moved to GSFC for Acoustics and Thermal Vacuum
- Local and Remote S/C Control (depends on the test)
  - S/C can be controlled from the local I&T workstations
  - S/C can be controlled from the remote MOC workstations
- Instrument GSE
  - If needed, can be located with the I&T GSE racks or near S/C

Deployment Tests

- Solar Arrays
  - 2x at S/C level, 1 G-Negated and 1 Pop and Catch
- Magnetometer Boom
  - G-Negated test at Boom Level
  - 2x Pop and Catch at S/C Level
- FIELDS Whip Antennas
  - 2x at S/C level, Pre-Env. Post ship to Cape
  - Caging Mechanism only, whip antennas not installed
- High Gain Antenna
  - 3x at S/C level, Pre-Env., In Tvac, Post ship to Cape
  - HGA Gimble is capable of articulating the HGA in a 1 G environment
- Instrument covers/doors
  - 2x at S/C level, Pre-Env. Post ship to Cape
  - Potentially once more in TVac

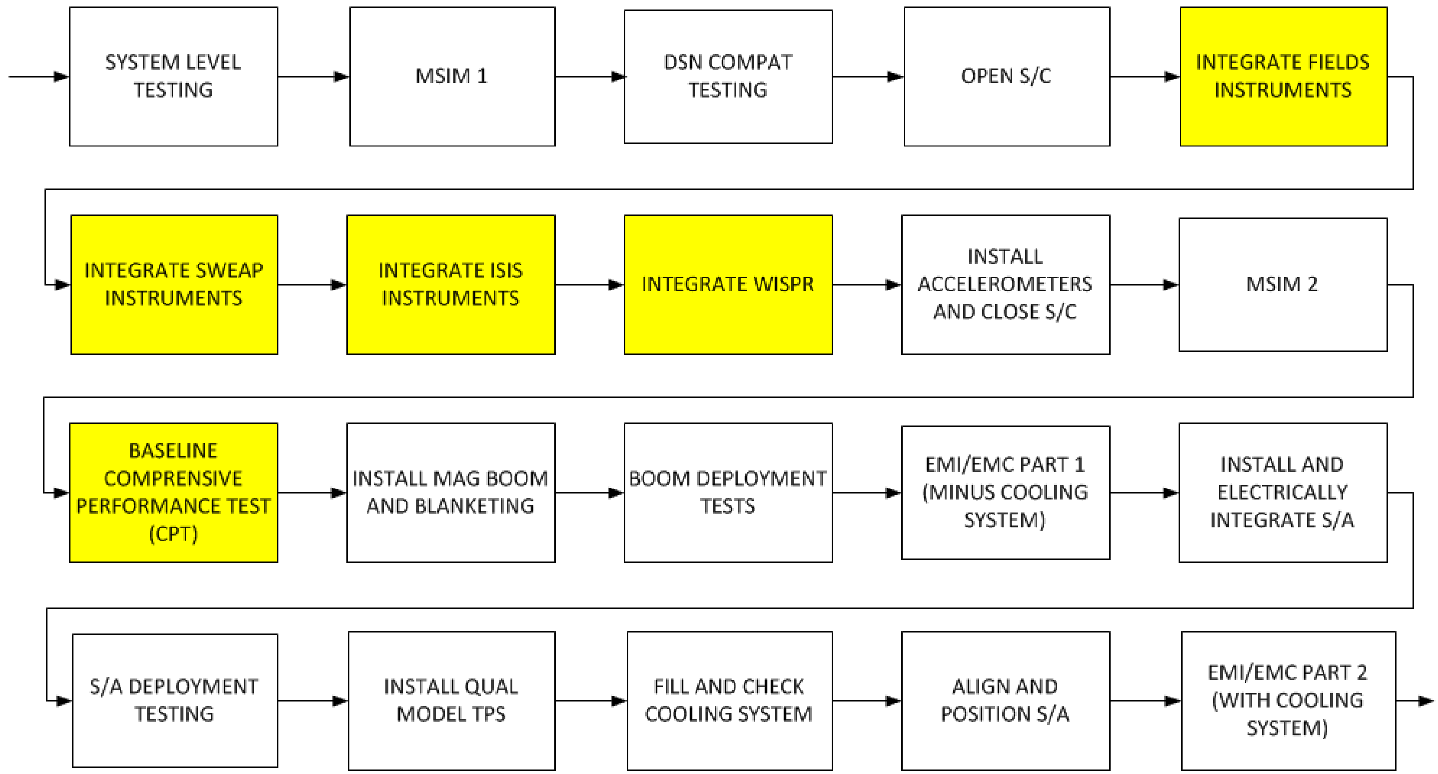
I&T Flow

SPP INTEGRATION AND TEST FLOW



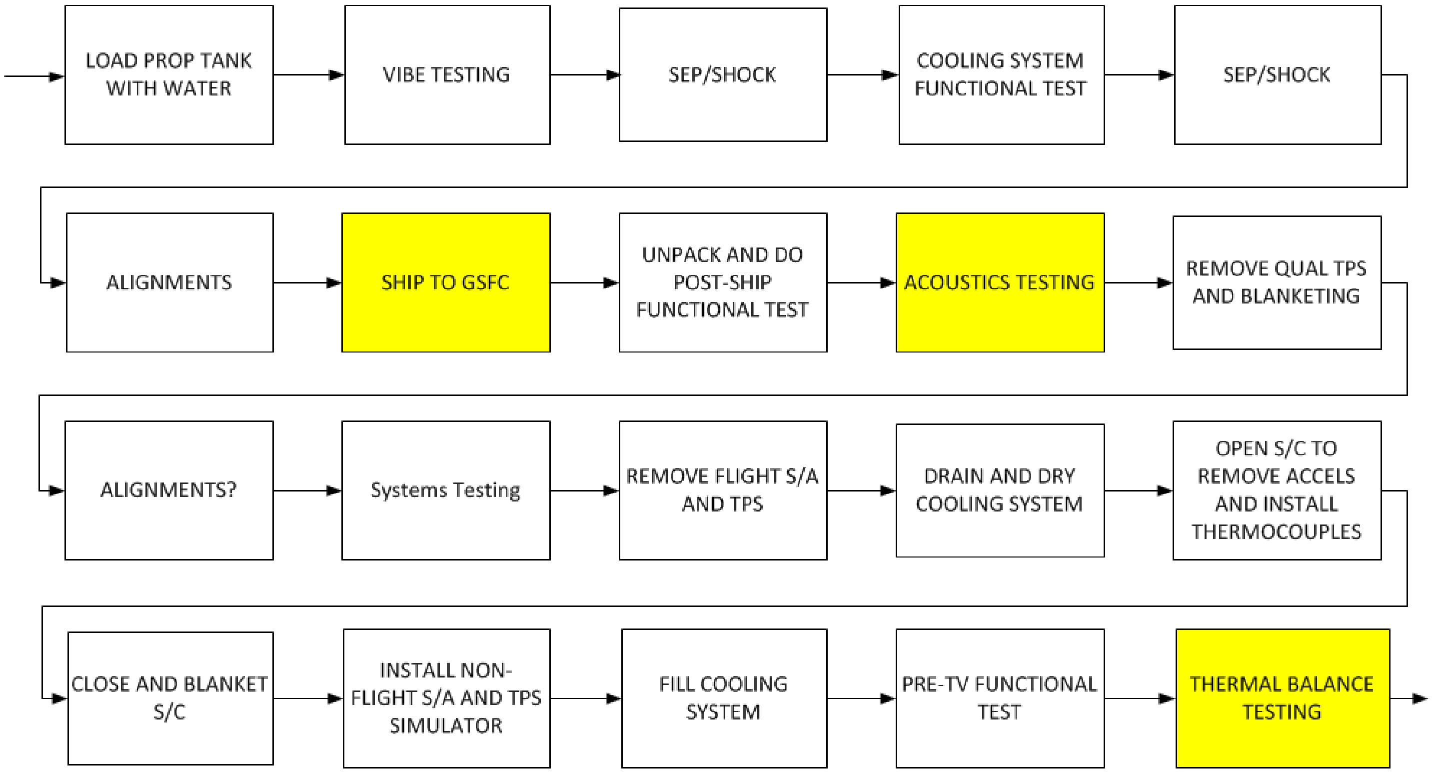
I&T Flow

SPP INTEGRATION AND TEST FLOW



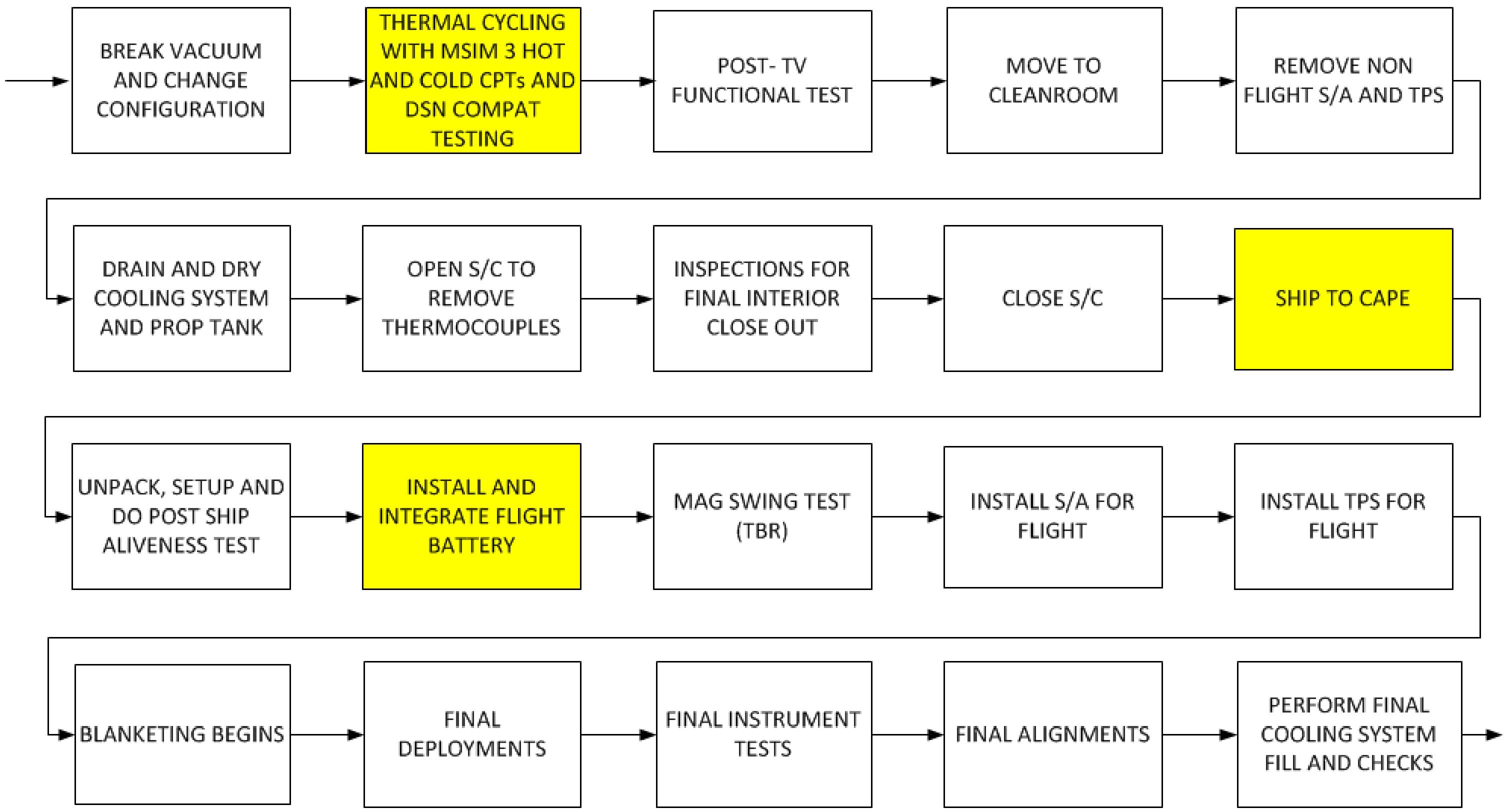
I&T Flow

SPP INTEGRATION AND TEST FLOW



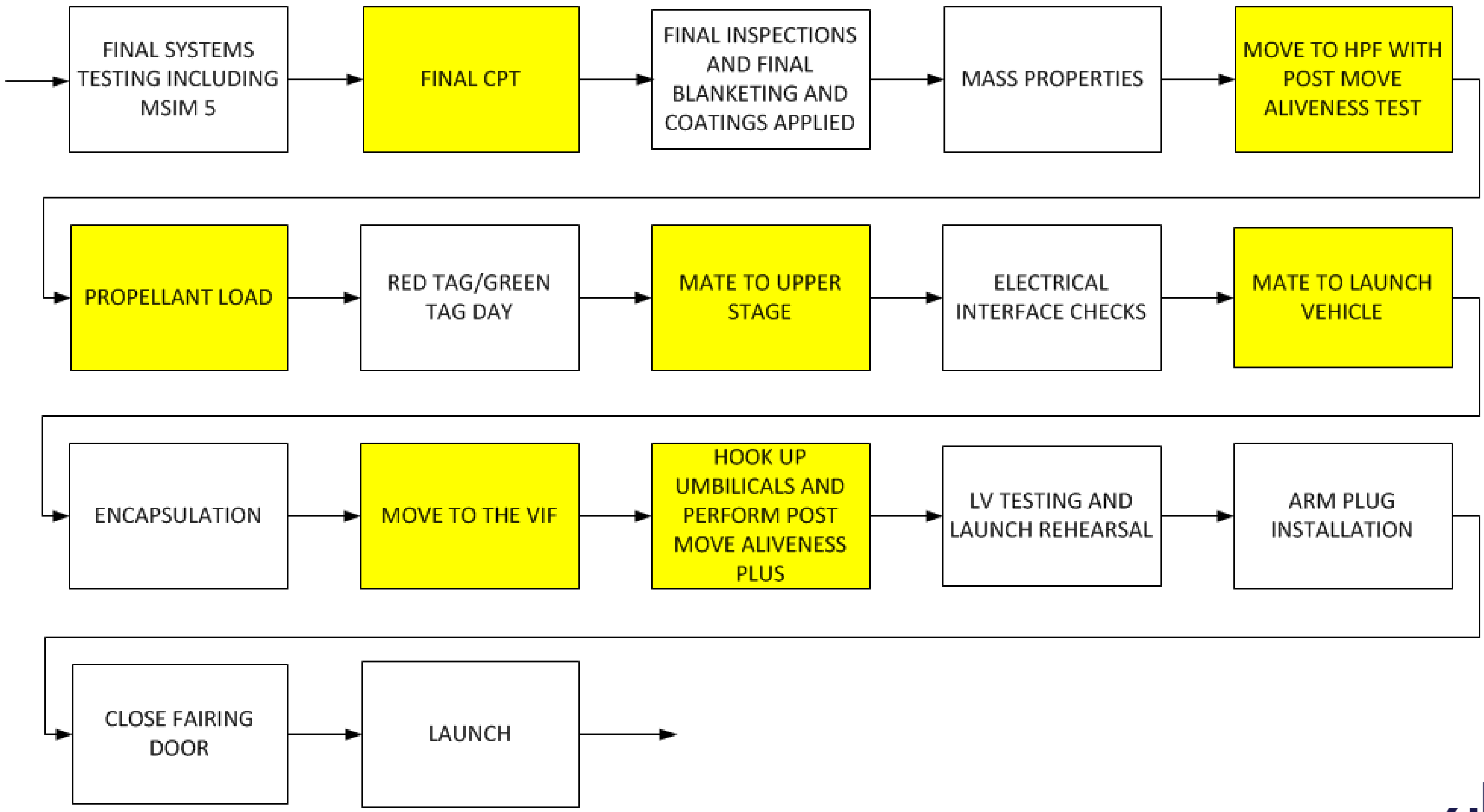
I&T Flow

SPP INTEGRATION AND TEST FLOW



I&T Flow

SPP INTEGRATION AND TEST FLOW



Work going forward

- **Work with Instrument teams to get more in depth information about their needs and desires during the I&T phase**
- **Work with the systems and subsystems teams to further define any special tests or test durations needed to give more definition to the Integration and Test Flow**
- **Work with the Mechanical and Thermal Leads to further define test configurations, sequencing issues and time/schedule concerns**
- **Will begin to hold the EGSE design reviews for the Umbilical Test Rack and the other I&T Test boxes**
- **Working with the requirements verification lead to assess which tests will be used to verify which requirements**
- **I&T Peer Review to happen summer 2014**

Conclusion

- **System Test Plan is released (7434-7300)**
- **Logistics Plan is released (7434-7301)**
- **Have a staffing plan**
- **Have a flow (framework) that has been vetted with systems and mechanical team at a high level, but needs to be fleshed out**
- **We have a 200 line schedule in the IMS which will grow in detail during phase C**

- **And I have a lot of enthusiasm**

I&T is Ready for Phase C!

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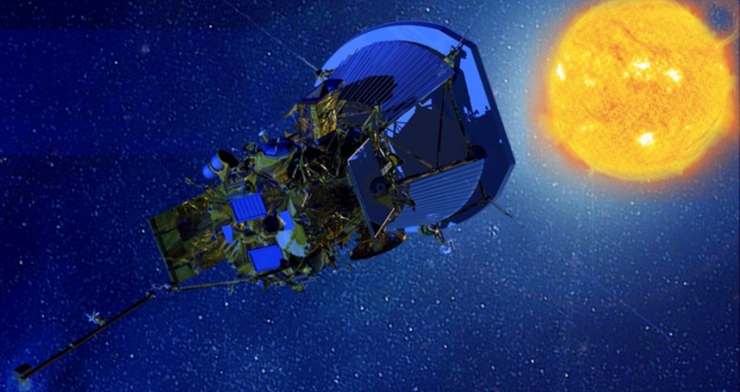


Mission Assurance

Luke Becker
SPP Mission Systems Assurance Manager

Luke.Becker@jhuapl.edu

13 – 16 January 2014

APL
The Johns Hopkins University
APPLIED PHYSICS LABORATORY

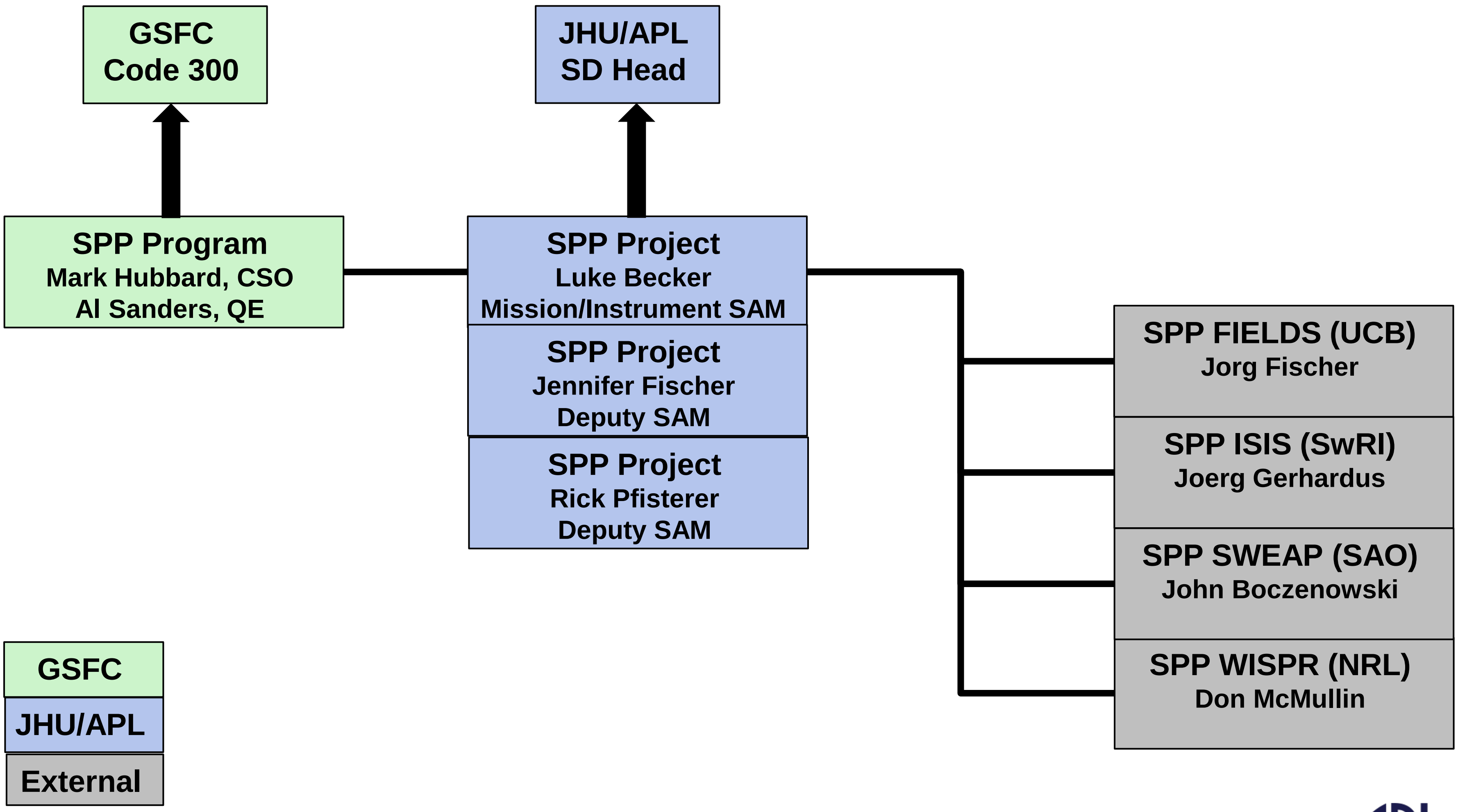
Outline

- Mission Assurance Disciplines
- Mission Assurance Organization (Independent Reporting)
- Program / Project Mission Assurance Counterparts
- Mission Assurance Requirements
  - SPP Project Performance Assurance Implementation Plan (PAIP)
    - Project Plans
    - Requirements Matrices
    - Flowdown of Applicable Requirements
    - Planned compliance/implementation
- Software Assurance
- Limited Life Item Process
- CDRL Status
- Mission Assurance Participation in Project Specific Boards
- Anomaly and Problem Failure Reporting (APFR)
- Summary of Phase B Mission Assurance Activities
- Planned Phase C/D Mission Assurance Activities
- Summary

JHU/APL Mission Assurance Disciplines

Disciplines residing within the Space Mission Assurance (SMA) Group	Disciplines NOT residing within the Space Mission Assurance (SMA) Group supporting mission assurance
• **Systems Assurance Management** • **Configuration Management** • **Software Assurance** • **System Safety** • **Supplier Management** • **Quality Engineering** • **Inspection** • **ESD** • **Risk Facilitator**	• **Contamination** • **EEE Parts** • **Materials & Processes** • **Reliability**

SPP Mission Assurance Organization Showing Independent Reporting



SPP Program Office
Mission Assurance Counterparts

GSFC	JHU/APL

• **CSO**
  • M. Hubbard
• **Quality Engineer**
  • A. Sanders
	• **Systems Assurance Manager**
	  • L. Becker (Mission)
	  • J. Fischer (Deputy)
	  • R. Pfisterer (Deputy)

• **Reliability**
  • A. Ingegneri
	• **Reliability**
	  • C. Smith

• **System Safety**
  • B. Smolnik / C. Fredlund
	• **System Safety**
	  • O. Ndu

• **Software Assurance**
  • A. Dasti
	• **Software Assurance**
	  • S. Smith

• **Materials and Process Control**
  • C. Powers
	• **Materials and Process Control**
	  • T. Langley

• **Parts Control**
  • C. Green
	• **Parts Control**
	  • D. Bonner

SPP Mission Assurance Requirements

- ***LWS-SPP-RQMT-0003A Solar Probe Plus (SPP) Project Mission Assurance Requirements (MAR) flowed to JHU/APL via the SOW.***
  - ***APL will implement a reliability, quality assurance, and safety program in accordance with the Solar Probe Plus Performance Assurance Implementation Plan (7434-9003).***
- **The Solar Probe Plus Performance Assurance Implementation Plan (PAIP) provides traceability to the AS9100 certified JHU/APL Quality Management System (QMS) and LWS-SPP-RQMT-0003A Solar Probe Plus (SPP) Project Mission Assurance Requirements (MAR).**
- **The JHU/APL SPP PAIP, 7434-9003 Rev C, has been reviewed and approved by both JHU/APL and GSFC. The SPP PAIP is the governing document for SPP Mission Assurance.**

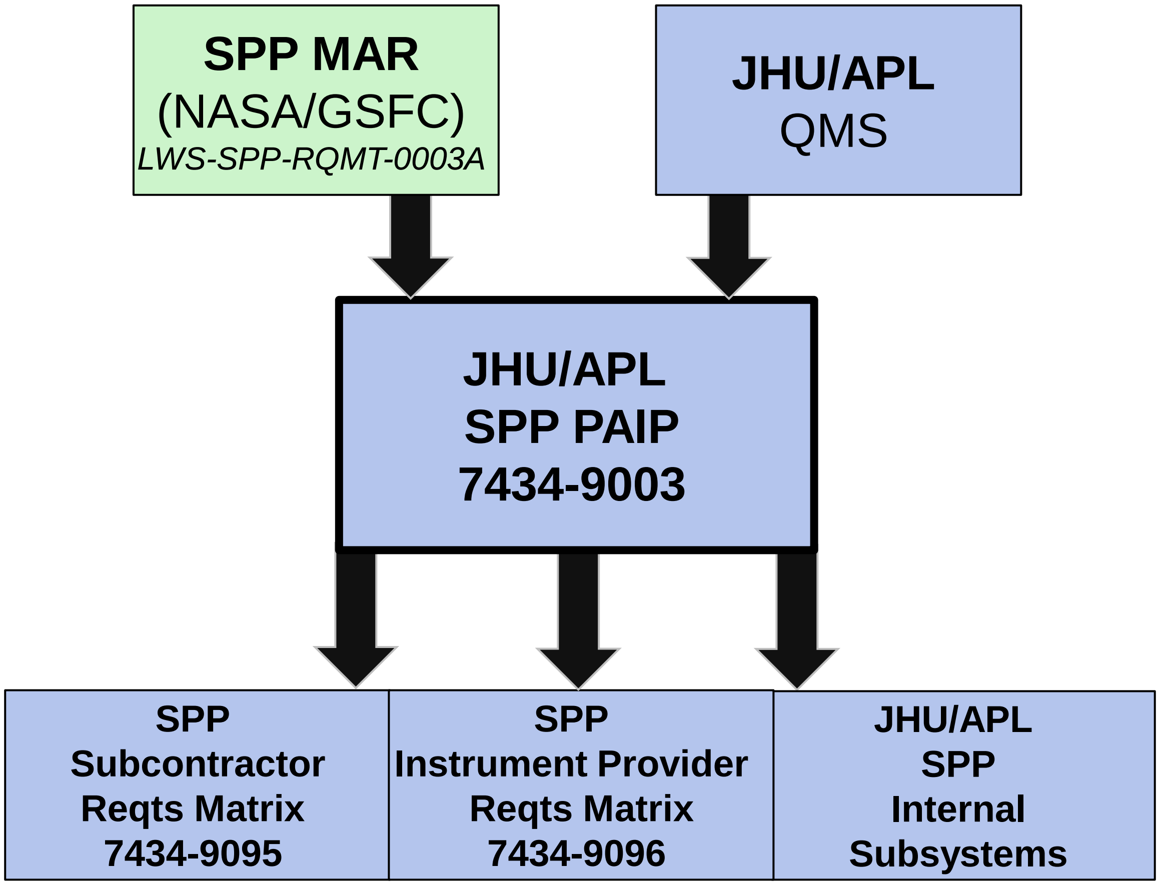
SPP Project Plans Invoked via the SPP PAIP

- **SPP Project Plans invoked when applicable as part of the PAIP**
- **Plans are under configuration management at JHU/APL within the Product Lifecycle Management (PLM) tool**

JHU/APL
SPP PAIP
7434-9003

7434-9006 SPP Configuration Management Plan
7434-9011 SPP Contamination Control Plan
7434-9041 SPP Reliability Program Plan
7434-9037 SPP Software Assurance Plan
7434-9013 SPP System Safety Program Plan
7434-9001 SPP Parts Control Plan
7434-9009 SPP Materials and Processes Control Plan
7434-9106 SPP Probabilistic Risk Assessment Plan
7434-9172 SPP Limited Life Items Plan

Flowdown of SPP Mission Assurance Requirements



Mission Assurance Requirements Matrices

- **Mission Assurance Requirements Matrices serve as:**
  - **A Requirements document that is tailored for the flowdown of applicable requirements per system, subcontractor, or instrument**
  - **A compliance matrix**
  - **A traceability matrix containing organizationally specific implementation plans traceable to to the SPP MAR**
  - **A verification matrix (requirements verified prior to PSR)**

REQUIREMENT ID	Requirement Text	Intended Compliance	Implementation	Verification
Unique #	The developer shall…	Comply, Comply with Caveat, Do Not Comply, N/A	Implementing process, procedure, plan	Artifact

Instrument Provider Requirements Flowdown

- **SPP Instrument Provider PAIP Matrices, 7434-9096:**
  - **- have been released**
  - **- flowed to each Instrument Team**
  - **- intended compliance and implementation plans have been identified**

- **Instrument Provider matrices are under configuration management at JHU/APL in PLM**
  - **7434-9096-01 UCB FIELDS**
  - **7434-9096-02 SAO SWEAP**
  - **7434-9096-03 NRL WISPR**
  - **7434-9096-04 SwRI ISIS**

JHU/APL
SPP PAIP
7434-9003

↓

SPP
Instrument Provider
Reqts Matrix
7434-9096

Spacecraft Subsystem Requirements Flowdown

- **SPP Subcontractor PAIP Matrices, 7434-9095,**
  - **have been released,**
  - **flowed to subsystems,**
  - **identified applicable requirements; compliance and implementation approach will be finalized prior to subcontract award**
- **Subcontractor PAIP Matrices are under configuration management at JHU/APL in PLM**

JHU/APL SPP PAIP 7434-9003

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SPP Subcontractor Reqts Matrix 7434-9095

- **7434-9095-01 Solar Array**
- **7434-9095-02 Propulsion System**
- **7434-9095-03 Solar Array Cooling System**
- **7434-9095-04 Solar Limb Sensor**
- **7434-9095-05 Star Tracker**
- **7434-9095-06 IMU**
- **7434-9095-07 Reaction Wheels**
- **7434-9095-08 TWTA**
- **7434-9095-09 TPS**
- **7434-9095-10 Upper Stage System**
- **7434-9095-11 Upper Stage Motor**
- **7434-9095-12 Gimbal/ECU**
- **7434-9095-13 Bus Structure**
- **7434-9095-14 TSA**
- **7434-9095-15 High Gain Antenna**
- **7434-9095-16 Louvers**
- **7434-9095-17 Power Converter**

JHU/APL Internally Developed Spacecraft Subsystem Requirements Flowdown

- **JHU/APL internally developed SPP subsystems follow the SPP PAIP**
- **JHU/APL SPP Mission Assurance personnel review and approve all SPP project documentation containing mission assurance requirements**
  - **Examples include**
    - **Purchase Instructions**
    - **Purchase Orders**
    - **Drawings**
    - **Plans**
    - **Procedures**

JHU/APL
SPP PAIP
7434-9003

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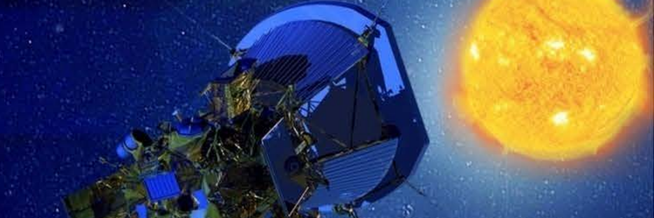
JHU/APL
SPP
Internal
Subsystems

SPP 7434-9003
PAIP Matrix Example



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REQUIREMENT ID	a=all i=internal (JHU/APL) e=external	7434-9003 JHU/APL SPP PAIP (The developer shall...)	GSFC SPP MAR Requirement Text (Original)	MAR Section or DID	Comply, Do Not Comply, Comply w/ Caveats N/A	Explanation of Do Not Comply, Caveats or N/A	Implementing Process/Procedure/Plan	rev	section
CM-XXX		***CONFIGURATION MANAGEMENT***							
CM-001	a	perform configuration management (CM) in support of the Solar Probe Plus Project.	The developer shall perform configuration management (CM) in support of the Solar Probe Plus Project.	2.2.4	Full Compliance No Caveats		SD-QP-480 Hardware Configuration Management Requirements and Implementation	a	Purpose
CM-002	e	apply their own institutional Configuration Management practices and procedures to configuration items in implementing the applicable CM requirements contained in this matrix and section 4 of the SPP Configuration Management Plan 7434-9006.	The developer shall document the CM process in a Configuration Management Plan to be submitted to the GSFC Program Office.	2.2.4	Not Applicable	External			
CM-003	i	document the CM process in a Configuration Management Plan to be submitted to the GSFC Program Office.	The developer shall document the CM process in a Configuration Management Plan to be submitted to the GSFC Program Office.	2.2.4	Full Compliance No Caveats		SD-QP-480 Hardware Configuration Management Requirements and Implementation	a	1.3
CM-037	a	perform and document configuration verification as assemblies are incorporated into higher-level assemblies and at major Project milestones (i.e. pre-environmental test, pre-ship, pre-launch, etc).	Configuration verification shall be performed and documented as assemblies are incorporated into higher-level assemblies and at major Project milestones (i.e. pre-environmental test, pre-ship, pre-launch, etc).	2.2.4	Full Compliance No Caveats		SD-QP-480 Hardware Configuration Management Requirements and Implementation	a	6.4
CTC-XXX		**CONTAMINATION CONTROL**							
CTC-001	a	prepare and implement a contamination control program per the requirements contained in the SPP Contamination Control Plan 7434-9011.	The developer shall prepare and implement a contamination control program (DID 13-1).	14.1	Full Compliance No Caveats		SPP Contamination Control Plan 7434-9011		
DV-XXX		**DESIGN VERIFICATION**							
DV-001	a	demonstrate a period of 300 hours of total powered test time at the instrument/box level, the last 100 hours of which are consecutive failure-free operation at the conclusion of their verification program prior to delivery to the spacecraft.			Full Compliance No Caveats		SD-QP-601 Space Flight System Test Requirements	-	4.6
DV-002	i	plan and implement a system performance verification program per the following requirements: - NPR 7120.5 NID-81 NASA Program and Project Management Processes and Requirements - NPR 7123.1A NASA Systems Engineering Processes and Requirements	The developer shall plan and implement a system performance verification program per the following requirements: - NPR 7120.5 NASA Program and Project Management Processes and Requirements - NPR 7123.1 NASA Systems Engineering Processes and Requirements	10.1	Full Compliance No Caveats		7434-9099 SPP System Verification and Validation Plan		
FPGA-XXX		**FIELD PROGRAMMABLE GATE ARRAYS**							
FPGA-001	a	have a documented flight FPGA development process that incorporates planning, staff training, requirements analysis, design specification, configuration management including name and version of all flight FPGA development software, test planning, code development, functional simulation, design synthesis, placing and routing, and post-route verification.	The developer shall have a documented FPGA development process that incorporates planning, staff training, requirements analysis, design specification, configuration management, test planning, code development, functional simulation, design synthesis, placing and routing, and post-route verification.	5.1	Full Compliance No Caveats		SD-QP-775 Spacecraft FPGA Design and Development Process	-	
FPGA-002	a	have a documented version control system for flight FPGA text and binary files (HDL, SDF, etc.) in place prior to any acceptance testing.	The developer shall have a documented version control system for FPGA text and binary files (HDL, SDF, etc.) in place prior to any acceptance testing.	5.3	Full Compliance No Caveats		SD-QP-775 Spacecraft FPGA Design and Development Process	-	
FPGA-003	a	place binary files (fuse files and memory loads) for flight parts under formal configuration management control.	The developer shall place binary files (fuse files and memory loads) for flight parts under formal configuration management control.	5.3	Full Compliance No Caveats		SD-QP-775 Spacecraft FPGA Design and Development Process	-	
FPGA-004	a	define required flight FPGA functions to be implemented.	The developer shall define required FPGA functions to be implemented.	5.4	Full Compliance No Caveats		SD-QP-775 Spacecraft FPGA Design and Development Process	-	
FPGA-006	a	provide a list to the SPP Project office by PDR of all flight FPGAs to be developed. The list shall include a detailed development schedule showing all planned flight FPGA peer review activities.	The developer shall provide a list to the SPP Project office by PDR of all FPGAs to be developed. The list shall include a detailed development schedule showing all planned FPGA peer review activities.	5.2	Full Compliance No Caveats		7434-9003 SPP PAIP		

Software Assurance

- **Performed by the SPP Software Assurance Engineer**
- **Project Software Assurance requirements are applied to Spacecraft Flight and Ground Software via the SPP Software Assurance Plan (7434-9037)**
- **Software Assurance coordinates efforts with NASA IV&V**

- **Project Software Assurance ensures that:**
  - **The project follows approved process to achieve quality, safety and reliability**
  - **Software process nonconformances are identified, analyzed and dispositioned**
  - **Accomplishments and metrics of software activity are reported to the SPP Systems Assurance Manager for inclusion in the SPP Project Monthly Status Report**
  - **Software products comply with agreed-upon standards**

SPP Limited Life Process

- **Limited Life Items Plan (7434-9172)**
  - **The plan establishes the process for defining and managing a listing of all limited life items used on SPP**
  - **Limited Life Item analysis is performed during the design and development phases**
  - **Limited Life Items Worksheet will be used to analyze potential limited life items**
    - **items with a lifetime known to be less than the mission lifetime requirement will require approval in the form of a project level waiver**

SPP Mission Assurance CDRL Status

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Name	Document Ref.	Assignee	DID Reference	Req Maturity
Performance Assurance Implementation Plan	7434-9003	Becker	MAR DID 1-1	Baseline
Software Development and Management Plan	7434-9042	Furrow	PM-06/MAR 5-3	Baseline
Risk Management Plan	7434-9005	Driesman	MAR 7-1	Final
Parts Control Plan	7434-9001	Bonner	MAR DID 11-1	Baseline
Materials and Processes Control Plan	7434-9009	Langley	MAR DID 12-1	Baseline
Nondestructive Evaluation Plan	SD-QP-776	Langley	MAR 12-5	Preliminary
Software Verification and Validation Plan	Part of 7434-9099	Furrow	MAR 5-2	Baseline
Ground Support Equipment Plan	Addressed in PAIP	Mitnick	MAR DID 6-2	Baseline
Ground Operations Equipment Plan	7434-7002	Mitnick	MAR DID 6-3	Preliminary
ESD Control Plan	QL2-060	Mitchell	MAR DID 10-1	Baseline
Software Quality Assurance Plan	7434-9037	S. Smith	MAR DID 5-1	Baseline
Contamination Control Plan and Data	7434-9011	Nichols	MAR DID 13-1	Preliminary
As-Designed EEE Parts List	7434-9001-01	Bonner	MAR DID 11-5	Preliminary
Limited-Life Items List	7434-9172-01	Becker	MAR DID 4-8	Preliminary
PRA and Reliability Project Plan	7434-9106/7434-9041	C. Smith	MAR DID 4-1	Baseline
Reliability Assessment and Prediction Report	Report	C. Smith	MAR DID 4-7	Preliminary
Probabilistic Risk Assessment	Report	C. Smith	MAR DID 4-2	Preliminary
FMEA and Critical Items List (CIL)	FMEA Spreadsheet	C. Smith	MAR DID 4-3	Preliminary
Qualitative Fault Tree Analysis	Report	C. Smith	MAR DID 4-4	Preliminary
Materials Usage Agreement	None Exist to Date	Langley	MAR DID 12-3	Preliminary
Materials Identification and Usage List	7434-9009-01	Langley	MAR DID 12-4	Preliminary
System Safety Program Plan (SSPP)	7434-9013	Ndu	MAR DID 3-1	Baseline
Mishap Preparedness and Contingency Plan	HQ/Program writes this	Ndu	MAR DID 3-11	Baseline
Range Safety Requirements Tailoring	In MSPSP	Ndu	MAR DID 3-3	Baseline
Missile System Prelaunch Safety Package (MSPSP)	7434-9010	Ndu	MAR DID 3-7	Preliminary
Orbital Debris Assessment Report	7434-9533	Guo	MAR DID 3-10	Preliminary
Material Selection List for Plastic Films, Foams, Adhesive Tapes	Referenced in MSPSP	Ndu	MAR DID 3-12	Preliminary
Radiation Forms and Analysis	Referenced in MSPSP	Ndu	MAR DID 3-13	Preliminary
Process Waste Questionnaire	Referenced in MSPSP	Ndu	MAR DID 3-14	Preliminary
Environmental Impact Statement	Referenced in MSPSP	Ndu	MAR DID 3-15	Preliminary
Operating and Support Hazard Analysis	In Hazard Report	Ndu	MAR DID 3-6	Preliminary
Hazard Analysis	In Hazard Report	Ndu	MAR DID 3-4	Preliminary
Hazards Verification Tracking Log	In Hazard Report	Ndu	MAR DID 3-8	Preliminary

Mission Assurance Support to Project Specific Boards

- **Mission Assurance personnel are currently supporting the following project level boards**
  - **Parts Control Board**
  - **Materials & Processes Control Board**
  - **Project Risk Board**

- **In addition to continuing support for the project boards listed above, during phases C/D, mission assurance personnel will support the following boards as required**
  - **Material Review Board**
  - **Change Control Board**
  - **Failure Review Board**

Anomaly and Problem Failure Reporting (APFR)

- **APFR System is a closed loop system that supports the nonconformance handling and material review board process**
  - **APFR will be used at JHU/APL for all flight SPP developed subsystems**
  - **APFR will be used once externally developed SPP flight hardware is delivered to JHU/APL**
- **APFR:**
  - **Assures that all incidents defined as Failures, Accidents, Problems, Surprises, Anomalies are recognized and a proper response action and close out occur**
  - **Assures awareness of the problem**
  - **Assures proposed dispositions do not introduce new problems**
  - **Triggers corrective action when appropriate to prevent recurrence of the incident**
  - **Supports the assessment of programmatic risk**
  - **Supports identification and analysis of trends within a subsystem or across multiple subsystems, systems, or projects**

Summary of Phase B Mission Assurance Activities

- **Flowed down and negotiated applicable SPP Mission Assurance Requirements to all Instrument Providers**
- **Mission Assurance Requirements Matrices have been flowed to subcontractors and are under configuration control at JHU/APL**
- **Project Mission Assurance personnel have been proactively engaged with GSFC, Instrument Providers, Subcontractors, and JHU/APL system and subsystem leads**

Planned Phase C/D Mission Assurance Activities

- **Maintain mission assurance relationships with all subsystems, instrument providers and major subcontractors to ensure applicable mission assurance requirements are being implemented**

- **Ensure all identified implementation plans/processes/procedures at JHU/APL, Instrument Provider Institutions, and Subcontractors are adequately developed and in place prior to the fabrication of flight hardware**

Mission Assurance Summary

- **Mission Assurance Requirements are in place and flowed down to JHU/APL, Instrument Providers, and Subcontractors as applicable**
- **Project Plans flowed from the PAIP are under configuration control**
- **Mission Assurance concurs with all current project level risks**
- **Mission Assurance disciplines across the project have been staffed with experienced personnel**

Mission Assurance is ready to proceed to Phase C

IV&V Program

SPP Mission Software IV&V

William Stanton

william.m.stanton@nasa.gov

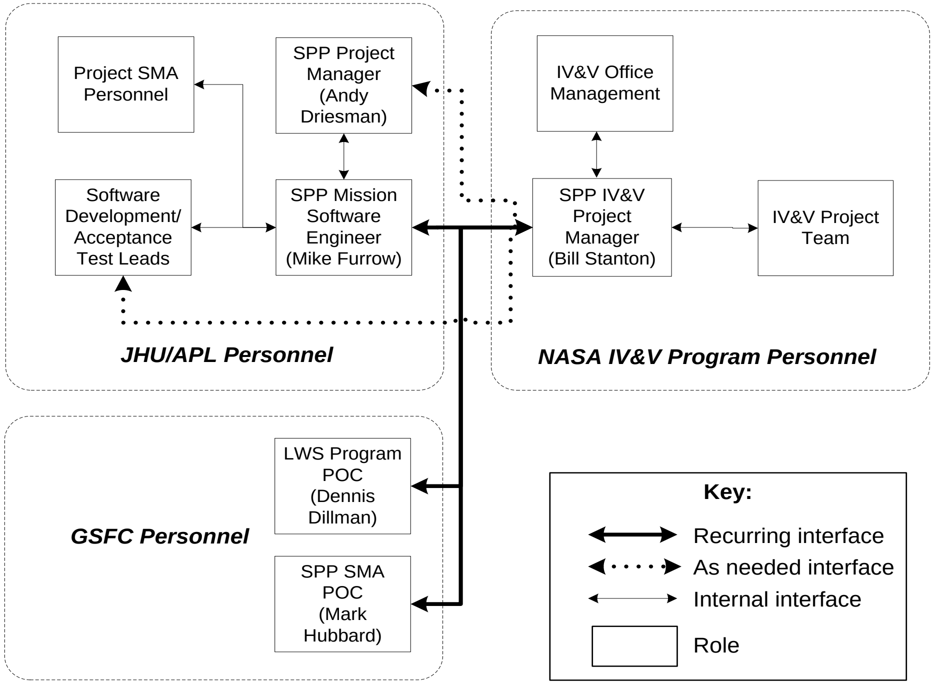
SPP IV&V Overview

- SPP IV&V started October 2012
- SPP IV&V is focused on safety and mission critical software
- SPP IV&V is oriented around the following principles:
  - Assuring that the software does what it is supposed to do
  - Assuring that the software does not do what it is not supposed to do
  - Assuring that the software does what it is supposed to do under adverse conditions
- SPP IV&V strives to identify defects when they are most value added to SPP, thereby mitigating project cost and schedule risk
  - Analysis findings and reports to be provided promptly following completion of analysis
- NASA IV&V intends to continue to provide assurance for SPP up to launch

IV&V Program

SPP IV&V Communication with JHU/APL

- SPP IV&V Project Execution Plan (IPEP) is documented and JHU/APL has concurred with it.
- Primary communication channel between IV&V and JHU/APL is through the IV&V Project Manager and the SPP Mission Software System Engineer
- IV&V relationship with JHU/APL and GSFC/LWS is positive
  - JHU/APL and GSFC/LWS are responsive to IV&V findings and artifact requests



IV&V Program

SPP IV&V Scope & Focus

- SPP IV&V Scope established using the IV&V Portfolio Based Risk Assessment (PBRA)
- SPP IV&V Scope is defined in both a functional (i.e. system capabilities) and software configuration item (CSCI) perspective
- SPP IV&V Focus is based on criticality of in-scope system capabilities and software entities as determined by PBRA results
- JHU/APL has concurred with SPP IV&V PBRA results

SPP Mission System Capabilities
Control Upper Stage Ascent and Separation from Observatory
Establish an Operational Observatory
Control Trajectory Correction Maneuvers (TCMs)
Maintain Attitude and Stabilization
Maintain an Operational Observatory
Monitor, Detect, and Respond to Faults
Manage Observatory Command and Data Handling
Telemeter Observatory Data during Ground Contacts

SPP Mission Software Entities (CSCIs)					
Flight	*Payload*	*Ground*	*Simulation*	*Test Set*	*Upper Stage*
Spacecraft Control (C&DH)	WISPR DPU	Planning	Testbed	PGS	Stage Assembly Software
Spacecraft Control (G&C)	FIELDS	Command & Telemetry		RF	
Boot	SWEAP	Assessment		RPM/ REM	
Autonomy	ISIS	Concord			
RF/XCVR		Tools			

IV&V Focus
No IV&V
Secondary Focus
Primary Focus

SPP IV&V Activities

- IV&V participated in the peer reviews of the SC FSW and GSW requirements and preliminary designs
- IV&V analyzed the following artifacts
  - Spacecraft Control, Boot and Ground Software Requirements
    - Began before requirements were baselined
    - Delta analysis performed on baseline released on 10/1
    - IV&V focus is subset of the L4 requirements related to the established SPP IV&V scope and focus
  - SPP Mission Software Architecture
  - SPP Spacecraft Control Software Architecture
    - Target of analysis is the FSW PDR material and allocation of L4 FSW requirements, that were analyzed by IV&V, to CSCs
  - SPP Mission Software V&V Plan

IV&V Program

SPP IV&V Assurance Status (as of 12/18/2013)

Flight	Payload	Ground	Simulation	Test Set	Upper Stage
Spacecraft Control (C&DH)	WISPR DPU	Planning	Testbed	PGS	Stage Assembly Software
Spacecraft Control (G&C)	FIELDS	Command & Telemetry		RF	
Boot	SWEAP	Assessment		RPM/REM	
Autonomy	ISIS	Concord			
RF/XCVR		Tools			

SPP Mission System Capabilities

- Control Upper Stage Ascent and Separation from Observatory
- Establish an Operational Observatory
- Control Trajectory Correction Maneuvers (TCMs)
- Maintain Attitude and Stabilization
- Maintain an Operational Observatory
- Monitor, Detect, and Respond to Faults
- Manage Observatory Command and Data Handling
- Telemeter Observatory Data during Ground Contacts

IV&V Focus

No IV&V
Secondary Focus
Primary Focus

IV&V Assurance Status

Future work
Current work, no open severity 1-3 issues
Work Complete, no open issues
Issue Resolution to be verified
Unresolved severity 3 issues
Unresolved severity 1 or 2 issues

SPP IV&V Summary

- SPP spacecraft flight software is ready to proceed with detailed design with the following constraints:
  - Completion of Traceability between L3 Spacecraft Requirements and L4 Spacecraft FSW Requirements
  - Proposed resolutions to all open high severity findings IV&V has with L4 Spacecraft FSW Requirements are concurred with by IV&V
- SPP ground system software is ready to proceed with detailed design
- SPP IV&V will
  - Verify the traceability between L3 Spacecraft Requirements and L4 Spacecraft FSW Requirements once it is completed
  - Validate any changes to L4 G&C and C&DH FSW requirements and architecture related to the established SPP IV&V scope and focus

BACKUP

Status of SPP IV&V TIMs (as of 12/18/13)

State	Issues 1	2	3	4	5	Total Issues	
Submitted	0	0	14	1	1	**16**	Unresolved
In Dispute	0	0	0	0	0	**0**	
Project Accepts Risk	0	0	0	0	0	**0**	
TBV	0	0	3	1	0	**4**	Waiting to verify resolution
Closed	0	1	9	1	4	**15**	Closed
Closed before Submitted	0	0	0	0	0	**0**	
Not to be Verified	0	0	0	0	0	**0**	
Withdrawn	0	0	1	0	0	**1**	
	0	1	27	3	5	**36**	

- There are unresolved high severity issues
  - 11 out of 14 high severity issues with SC FSW Requirements related to G&C functionality will be reviewed by JHU/APL when the G&C Subsystem Lead and G&C FSW Lead scrub the G&C FSW requirements before Mission PDR
  - 3 out of 14 high severity issues with SC FSW Requirements related to C&DH functionality are actively being reviewed by JHU/APL based on status JHU/APL provided to IV&V in meeting on 12/4. IV&V awaits JHU/APL final proposal for the resolution of these TIMs.
- 3 severity 3 issue requires verification by IV&V
  - IV&V will verify these issues are resolved with the next version of requirements expected to be released in January before the Mission PDR

IV&V TIM Severity Definitions

Severity	Capability Affected	Success Criteria	Safety	Test	Cost & Schedule	Other
1 Catastrophic	Loss of an essential capability OR Complete loss of mission critical asset	Inability to achieve minimum mission success criteria	Causes loss of life or injury	N/A	N/A	N/A
2 Critical	Degradation of an essential capability OR Damage/destruction to mission asset which affects performance	Impact to the accomplishment of a mission objective	N/A	Essential capability not tested	Significant cost increases or schedule slip	Significant reduction to requirements margins or design margins
3 Moderate	Degradation of system dependability OR Loss of a non-essential capability	Impact to the accomplishment of extended/optional mission objectives	N/A	Essential capability inadequately tested	Cost or schedule impact resulting from redesign, reimplementation, and/or retest	Degradation of an essential capability or inability to accomplish mission objective, but with a known workaround
4 Minor	Degradation of a non-essential capability	N/A	N/A	Non-essential capability inadequately tested	Defect impacting maintainability on current mission or reuse on future missions	Creates inconvenience for operators, crew or other projects' personnel
5 Communications Or Editorial	Defect impacting documentation and communication clarity					

IV&V TIM State Definitions

- **Closed** – Issue submitted and verification of the implemented resolution completed to support closure
- **Closed Before Submitted** – Issue closed prior to submission based on receipt of a new artifact including the implemented resolution
- **Not To Be Verified** – Low severity issue (e.g., editorial issues) that will not be verified by IV&V
- **Project Accepts Risk** – Project acknowledges issue but accepts the risk of doing nothing to close it
- **In Dispute** – Issue that has open questions about the proposed closure response/resolution
- **Submitted** – Issue submitted to the project that is under evaluation by the project; pending resolution
- **To Be Verified** – Closure information submitted by the project; pending updated artifacts and verification/closure by IV&V
- **Withdrawn** – Issue determined to be invalid based on project feedback; subsequently closed

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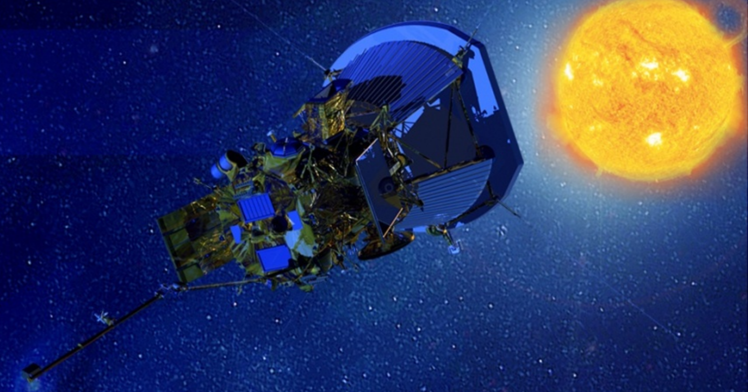


System Safety

Obibobi K. Ndu

Obibobi.ndu@jhuapl.edu

13 – 16 January 2014

The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Agenda

- **Program objectives and implementation**
- **System Safety Program Documentation Status**
- **Requirements**
- **Safety Coordination and Reporting**
- **Preliminary safety assessments**
- **System Hazard Identification**
- **Risk Assessment**
- **Range Safety**
- **Conclusion**

System Safety Program Objectives and Implementation

- **Objectives**
  - Avoid loss of life, injury or illness to personnel caused by mishaps
  - Identify and assess hazards associated with SPP hardware, software and operations during all program phases
  - Establish safety risk acceptance authority and associated risk levels
  - Ensure mitigation of hazards to acceptable levels
  - Provide safety support for hazardous operations at APL, Astrotech Florida, and KSC
  - Generate documentation for Project Safety Reviews
- **Implementation**
  - The SPP System Safety Program Plan 7434-9013 describes safety roles and responsibilities and describes the process for identification and mitigation of hazards

System Safety Documentation Status

- **Safety requirements have been established and disseminated**
- **System Safety Program Plan (7434-9013) – Released and submitted for GSFC Review**
- **MSPSP (7434-9010) – Released and submitted for GSFC review**
  - **Safety Risk Management Plan**
  - **Systems Descriptions**
  - **Preliminary Hazard Analysis**
  - **NASA 8719.24 Compliance Matrix**
  - **Mishap Plan Input**
- **Upper Stage Safety Data Package**
- **Instrument MSPSP Input**
  - **Range safety compliance status**
  - **Preliminary hazard identification**

Requirements

- **Identified in the Project PAIP (7434-9003)**
- **Sourced from the following:**
  - **ARDES contract**
  - **NASA safety standards**
  - **Range safety standards**
  - **Project safety plans**
  - **Facility safety policies and manuals**
    - **APL, ASO FL, KSC, Launch facility**
- **Communicated to subcontractors and Instrument teams via:**
  - **Statements of Work**
  - **PAIP Matrices**
  - **System Specifications**
  - **Interface Control Documents**

Safety Requirements List

- **Applicable safety documents**

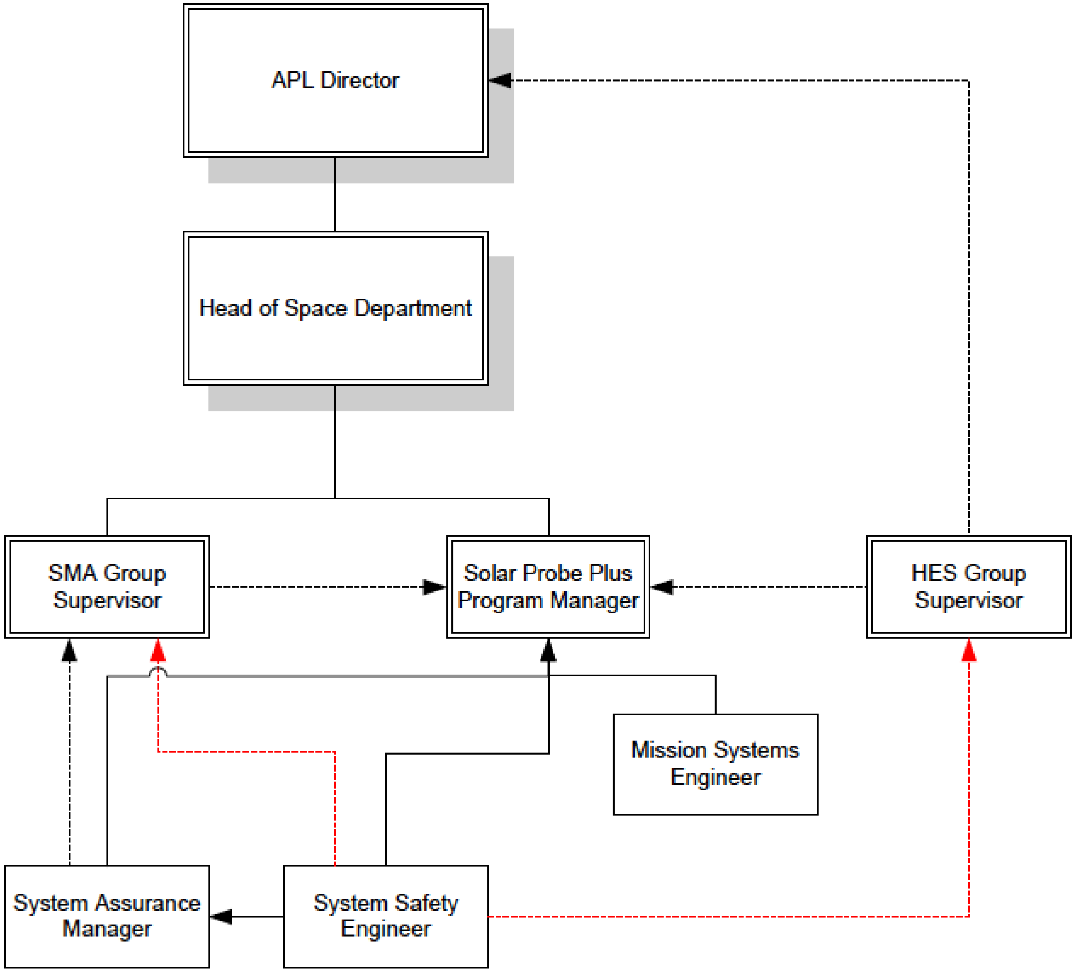
NASA-STD 8719.24	NASA Expendable LV Payload Safety Requirements
AFSPCMAN 91-710	Range Safety User Requirements (NASA-STD 8719.24)
NPR 8715.3	NASA Safety Manual
NPR 8715.7	ELV Payload Safety Program
NPR 8713.3B	NASA General Safety Program Requirements
NASA-STD 8719.13	Software Safety Standard
KHB 1710.2D	KSC Safety Practices Handbook
SD-QP-301	Space Department Safety Policy
ASOF-FACL-M0008	ASO FL Facility Safety Manual
TBD	Launch Vehicle Safety Document
500-PG-8715.1.2B	Applied Engineering and Technology Directorate Safety Manual
549-WI-8715.1.3A	Safety Evaluation Process

Safety Coordination

- **NASA HQ**
  - SMSR – Safety and Mission Success Review
- **LWS Program**
  - SPP NASA Sponsor
  - SPP MSPSP delivery to PSWG/Range
- **JHU APL**
  - Mission Integrator
  - SPP MSPSP delivery to NASA Program Office
- **Orbital Sciences/ATK/General Dynamics**
  - Upper Stage Integrator/Motor/Motor Case
  - Upper Stage MSPSP delivery to APL
- **Instrument Teams**
  - Instrument Safety Input to MSPSP – Requirements Compliance, Safety Data Package
- **Subcontractors**
  - Safety Input to MSPSP –Safety Data Package

APL Safety Reporting

- System Safety function resides in Space Mission Assurance Group
- System Safety Engineer develops and implements the Safety Program and per requirements on behalf of the Program Manager
- System Safety engineer reports safety input to the SAM for mission assurance coordination
- Independent Safety Reporting
- Laboratory-level Safety Organization for Occupational Safety & Health
  - Resource for Program Safety



Preliminary Safety Assessments

- Preliminary Software Safety Criticality Determination – Completed
  - Per GPR 7150 and NASA STD 8719.13B
- FMEA Review - Completed
  - 1S, 2S severity category failure modes that may occur prior to separation have relevance to system safety
- RF safe distance calculations for all transmitters – 1QCY14
- Room oxygen displacement rate (purge) – confined space (Upon confirmation of project I&T facility) – 1QCY14
- MGSE Tip-over analysis – Phase C activity (as project MGSE are designed)
- Ground Operations Assessment – Phase C activity

Hazardous Operations

- Catastrophic (not all inclusive)
  - Propellant loading operations
  - Mass Properties test
  - Upper Stage lift and mate operations
  - Battery charging operations
  - Spacecraft lifts
  - Cooling System environmental tests
  - TPS integration
  - HGA operations (energized)
- Critical (not all inclusive)
  - Pyro installation
  - Solar array deployments
  - Boom deployments

Hazard Mitigation and Verification

- Protection systems and fail-safe design
  - Safety critical loads are serviced through dual fault-tolerant safety buses
  - Safe plugs are used during ground test operations
- Isolation and containment of potential sources of hazardous energy
  - Radioactive sources (GSE) are encased within material that blocks radiation
  - RF hat couplers prevent RF exposure
  - Electrical insulation
  - Blast shields
- Limiting exposure to hazards procedurally
  - Maintaining a safe state for as long as operationally possible, e.g. limiting HVPS activation for an instrument
  - Establishing safe zones during hazardous operations
- Training, Protective Equipment, Warnings

Risk Assessment

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- **Initial risk matrix prior to inclusions of controls**

Initial Risk Matrix

		PROBABILITY				
		A	B	C	D	E
SEVERITY	I			*2*	*5*	
	II			*5*	*2*	
	III		*1*	*4*	*4*	
	IV	*1*			*1*	

⇒

Final Risk Matrix

		PROBABILITY				
		A	B	C	D	E
SEVERITY	I					
	II					
	III					
	IV					

Range Safety Status

- **Range Introduction Meeting**
  - **May 30, 2013**
  - **PSWG established for the SPP Project by KSC**
  - **Tailoring process underway**
- **Preliminary MSPSP submitted through GSFC**
- **Revised MSPSP to be submitted post MPDR**
  - **Incorporate GSFC review**
  - **Incorporate Instrument and subsystem PDR data**
  - **Incorporate Upper Stage Safety Data**
- **Support Phase I Safety Review at MPDR+45 (exact date TBD)**

Conclusion

- **Summary**
  - **Safety requirements identified and communicated as needed**
  - **Responsive safety program plan developed**
  - **Requirement compliance status reviewed and documented**
  - **PDR-Level safety analysis completed**
  - **Safety documentation completed and submitted**

- **System Safety is ready to proceed to Phase C.**

BACKUP

System Hazard Identification

- **Hazards by system and category**

SPP Systems	Sec No.	Acceleration	Asphyxiation	Contamination	Corrosion	Electrical	Fire / Explosion	Impact	Pressure	Ionizing Radiation	Non-Ionizing Radiation	Temperature	Toxic	Total
Structure	5.1							1						1
Power	5.2					2	1	1						4
Thermal Control	5.3								2					2
RF Communication	5.4										1			1
Propulsion	5.5						1		1					2
Guidance and Navigation	5.6													
Command & Data Handling	5.7													
Instruments	5.8					1		3		1				5
Software	5.9													
Ordnance (+NEI)	5.10							1						1
Hazardous Materials	5.11													
Ground Support Equipment	6.0		1			1		3	1					6
System Interface	8.0					2	1	2						5
Total			1			6	3	11	4	1	1			27

Solar Probe Plus

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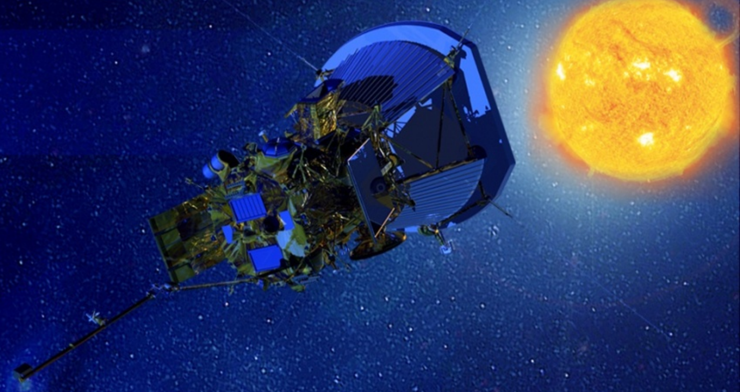


Contamination Control

John Nichols
Lead Contamination Control Engineer

john.nichols@jhuapl.edu

13 – 16 January 2014

The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Agenda

- Driving Requirement
- Contamination Control Plan (CCP)
- Contamination Outgassing Model
- Bakeout Philosophy
- Integration and Test
- Launch Site
- Special Topic – Thermal Protection Shield (TPS)
- Special Topic – Solar Array Contamination
- Future Work
- Summary

Driving Requirement

- **Per the Solar Probe Plus (SPP) Performance Assurance Implementation Plan (PAIP)**
  - The developer shall prepare and implement a contamination control program per the requirements contained in the SPP Contamination Control Plan 7434-9011
  - SPP CCP 7434-9011 (preliminary version) is in PLM
    - Received and implemented comments from instruments, subsystems and project management

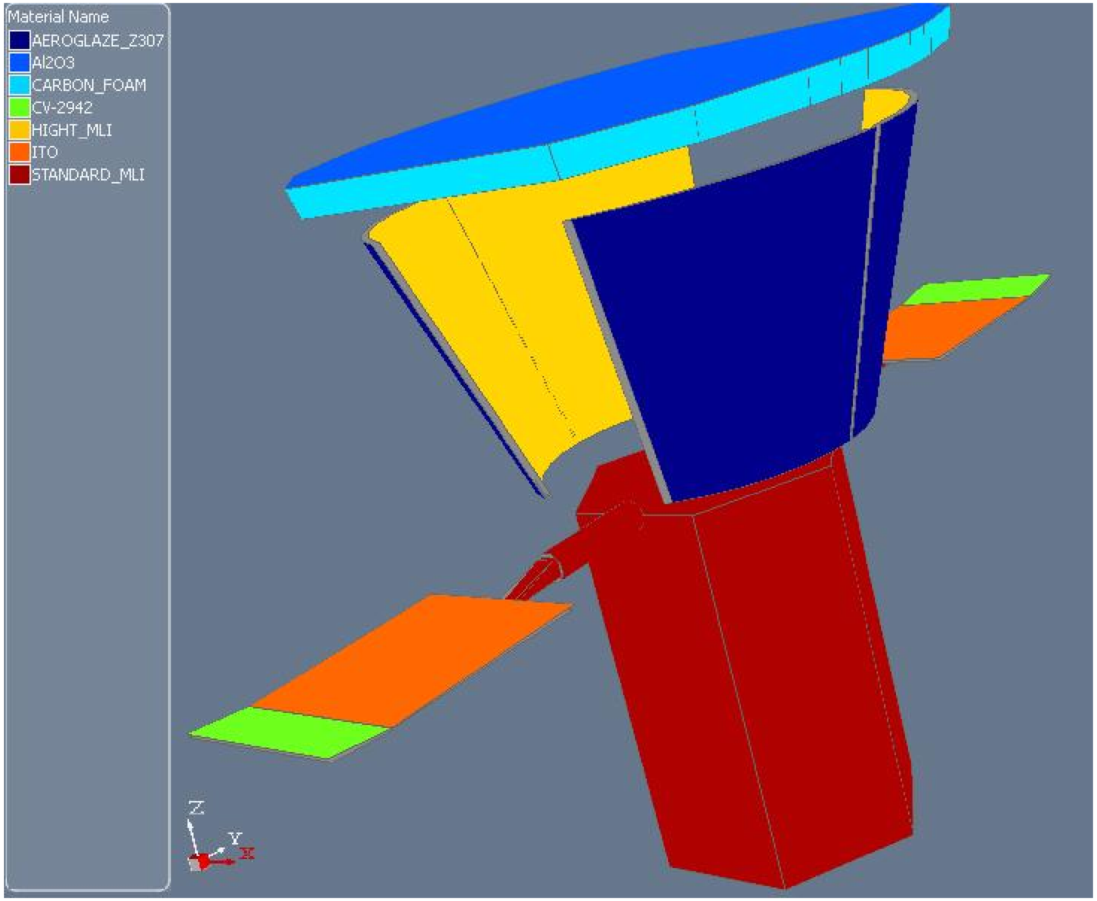
Contamination Control Plan (CCP) Development

- **Preliminary Version Focus**
  - Surface cleanliness requirements
  - VC2 unless otherwise stated
  - No molecular requirements imposed by S/C on subsystems or instruments (self-imposed molecular requirements are shown in CCP)
    - UV inspection requirements in lieu of molecular requirements
- **Formal Release of CCP**
  - 60 days prior to CDR
- **Focus of CCP Updates**
  - Incorporate outgassing model results in the form of bakeout requirements (currently mostly TBDs)
  - Populate other TBDs
    - Section 9 Environmental Testing
    - Section 10 Shipping Preparations

Modeling Introduction

SYSTEMA / Outgassing

- **Outgassing modeling in progress using Astrium's SYSTEMA package**
- **SYSTEMA / Outgassing includes**
  - Interactive model builder and interface with CAD tools
  - Evaluation of deposition of contaminants on the spacecraft surfaces (e.g. mirrors, thermal coatings, etc.) as function of time
  - Interactive 3D display for pre and post-processing



Modeling Details

- **Outgassing calculation**
  - Computation of mass transfer factors between surfaces (Monte Carlo)
  - Time integration of deposits
- **Processes included**
  - Ejection of contaminant molecules from spacecraft materials
  - Deposition onto spacecraft due to direct, scattered or re-emitted flux
  - Re-emission of deposited contaminant molecules
- **Material properties required as input to the model are derived from ESTEC test method (similar to ASTM E1559) or CNES test method**
- **Dependence of outgassing rates on surface temperatures is included in the model**
- **Model will continue to be refined until CDR**
  - Provide bakeout requirements for CC Plan between PDR and CDR

Bakeout

- **Bakeout Philosophy**
  - Only perform bakeouts when needed
    - Rely on outgassing model to avoid unnecessary bakeouts
    - Target component and subsystem level bakeouts to provide acceptable outgassing at the spacecraft and instrument level
  - Typical outgassing sources
    - Have direct line-of-sight exposure to a critical surface
    - Are vented toward a critical surface
    - Operate at a higher temperature than the critical surface
  - On-orbit bakeout
    - Removal of water and other vapors that outgas from nonmetallic materials and coatings
    - Use outgassing model and S/C venting methodology to determine on-orbit bakeout criteria

Integration & Test

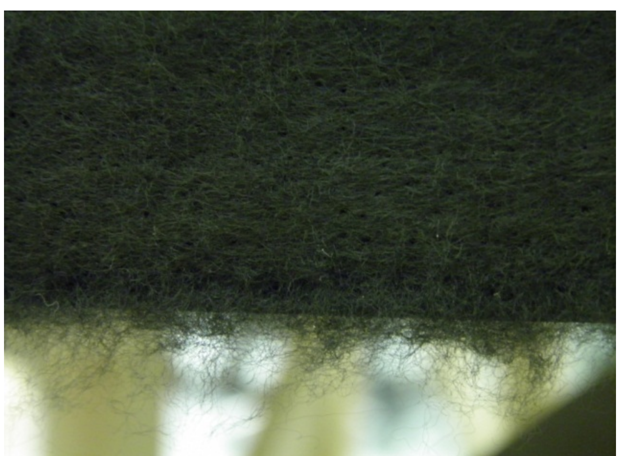
- **Baseline Integration Facility is APL Building 23**
  - 2000 sqft. of ISO Class 7 Horizontal Flow – High Bay
  - 1500 sqft. of ISO Class 8 Vertical Flow – High Bay Staging Area
  - 1700 sqft. of ISO Class 7 Vertical Flow – High Bay Integration Area
  - Since 2010 – new ceiling, HEPA's & air handlers for improved performance
- **GN_2 Purge**
  - Liquid nitrogen boil-off throughout the facility
  - Purge suitcases: < 0.1 ppm hydrocarbons, < 1.0 ppm H_2O and < 1.0 ppm O_2
- **Continuous Real-Time Particle Monitoring**
- **Adjacent Precision Cleaning and Verification Facilities**
  - 450 sqft. of ISO Class 5 Vertical Flow
- **Clean EMI Tent**
  - Provides ISO Class 8 EMI environment in Bldg 23 High Bay
- **Adjacent Environmental Test Facilities**
  - Multiple vacuum chambers
  - Vibrational and Acoustical Test Facility – capable of ISO Class 8

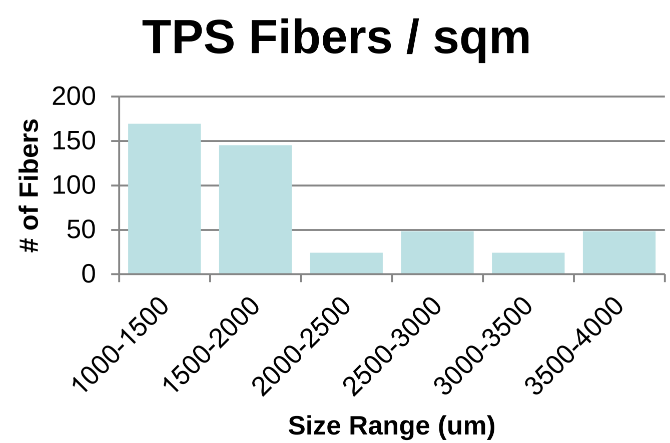
Launch Site Contamination

- **There will be an SPP Launch Site CC Plan**
  - Typically generated after CDR
  - Due at L-18 months
- **General Information about the Vehicle Integration Facility (VIF)**
  - The VIF is a non-clean industrial building
  - Hardware cleanliness is highly dependent on personnel protocols
  - Cleanroom garments are required for work inside fairing only
  - The fairing will be cleaned and verified to VC2 + UV
  - The air class provided to the payload compartment is guaranteed to meet Class 5,000
    - High volume, turbulent, stiff breeze at all doors
  - Fairing air is filtered using HEPA filters and activated charcoal filters
  - APL has previously positioned a particle counter probe near fairing wall using an umbilical for real-time particle monitoring
  - Grade B GN_2 is guaranteed at the launch facilities

Thermal Protection Shield (TPS) Contamination Mitigation

- **TPS edge closeout material**
  - Initial data suggests that the closeout material is 100% effective at containing particulate generated by the Carbon-Carbon foam
  - Carbon felt (Fiber Materials Inc.) is the closeout material (see image)
  - Surface area of the TPS edge (felt) is ~0.85 m^2
  - Felt produces fibers per the distribution (lower right)
    - 460 fibers (of average length 1925 um) per m^2
  - Note: Fibers produced during TRL-6 TPS Vibe Test
- **SWEAP is modeling the particle redistribution during launch to understand effect on the SWEAP Solar Probe Cup (SPC)**
- **Requirement to be defined in early Phase C**
- **Alternative edge close out materials will be evaluate as needed**





Solar Array Contamination

- **Spacecraft powered by solar arrays have reported significant degradation when operating in high irradiance, high radiation and high temperature environments on extended missions**[i]
  - Often not measurable on orbit until > 10,000 equivalent sun hours
  - SPP will see solar array degradation
  - Degradation is associated with “darkening” of solar arrays
    - May not be seen visually, may be a UV or IR absorbsance
- **Execute a series of experiments with the following objectives**
  - Identify degradation mechanism (assuming it’s related to outgassing) – i.e. look for “darkening”
  - Understand the effects of temperature, UV irradiance and charged particle (electrons and protons) interactions independently and in combination
  - Establish a technique for observing degradation < 10,000 equivalent sun hours
  - Use experimental data to predict degradation rate for SPP arrays

[i]*Toyota, Hiroyuki et. al., BepiColombo Mercury Magnetospheric Orbiter Solar Array Development, Proceedings of the 37th Photovoltaic Specialists Conference, 2011*

Test Results

- **Test Setup**
  - Vacuum chamber with thermal shroud and platen
  - Deuterium and Xenon UV lamps capable of 11 suns output
  - 50 KeV electron flood gun
  - RGA and TQCM
  - Ellipsometer
  - UV-VIS spectrometer
  - Samples in UV (11 suns) at +175C and samples NOT in UV (1 sun) at +145C
- **Major Findings:**
  - Established a method for measuring/estimating accumulation rates using ellipsometry
  - All silicone materials (DC93-500, CV-1142, etc.) outgas similar methylated siloxane fragments that appear to be mostly negatively charged
  - Thermal is responsible for the outgassing rate
  - UV is responsible for material accumulation (adsorption)
    - Siloxanes are permanently photo-fixed to surfaces under UV
    - Surface charge strongly affects the accumulation rate
  - Electron and protons are thought to cause “darkening” through film structural changes
  - UV and electrons (and possibly protons) combine to create degradation

Future Work

- **Phase C Activities**
  - PDR to CDR
    - Update and release CC Plan
    - Complete outgassing modeling including any outgas testing
    - Complete Solar Array materials testing
    - Mitigate particulate risks associated with TPS edge closeout material
    - Develop and deliver CC Protocol Training
    - Prepare facilities
  - Post CDR
    - Support I&T efforts with cleanroom use, precision cleaning & bakeouts
    - Receive subsystem and instrument hardware for integration
    - Develop and release Launch Site CC Plan
    - Support environmental test and shipment

Summary

- **Continue to prepare facilities and personnel for I&T**
- **Continue to update CC Outgassing Model and feed bakeout requirements into CC Plan**
- **Provide TPS edge closeout solution by CDR**
- **Increased understanding of solar array degradation**
- **Contamination Control is ready for Phase C**

Solar Probe Plus

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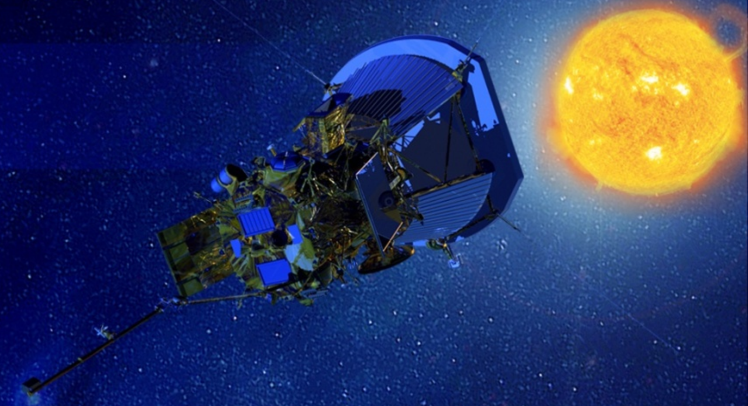

EEE Parts Status

David Bonner
Lead Parts Engineer

david.bonner@jhuapl.edu

13 – 16 January 2014

The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Agenda

- Review EEE Parts Requirements
  - Screening and Qualification
  - GIDEP
  - Stress Analysis
  - Deliverable Items
- APL EEE Parts Processing
- Overview of the Parts Control Board (PCB) Process
- Update on Phase B Status
  - Spacecraft Parts
  - Instrument/Sub-contract Parts
- Review of Critical Items
- Future Plans for Phase C
- Conclusion

EEE Parts Requirements

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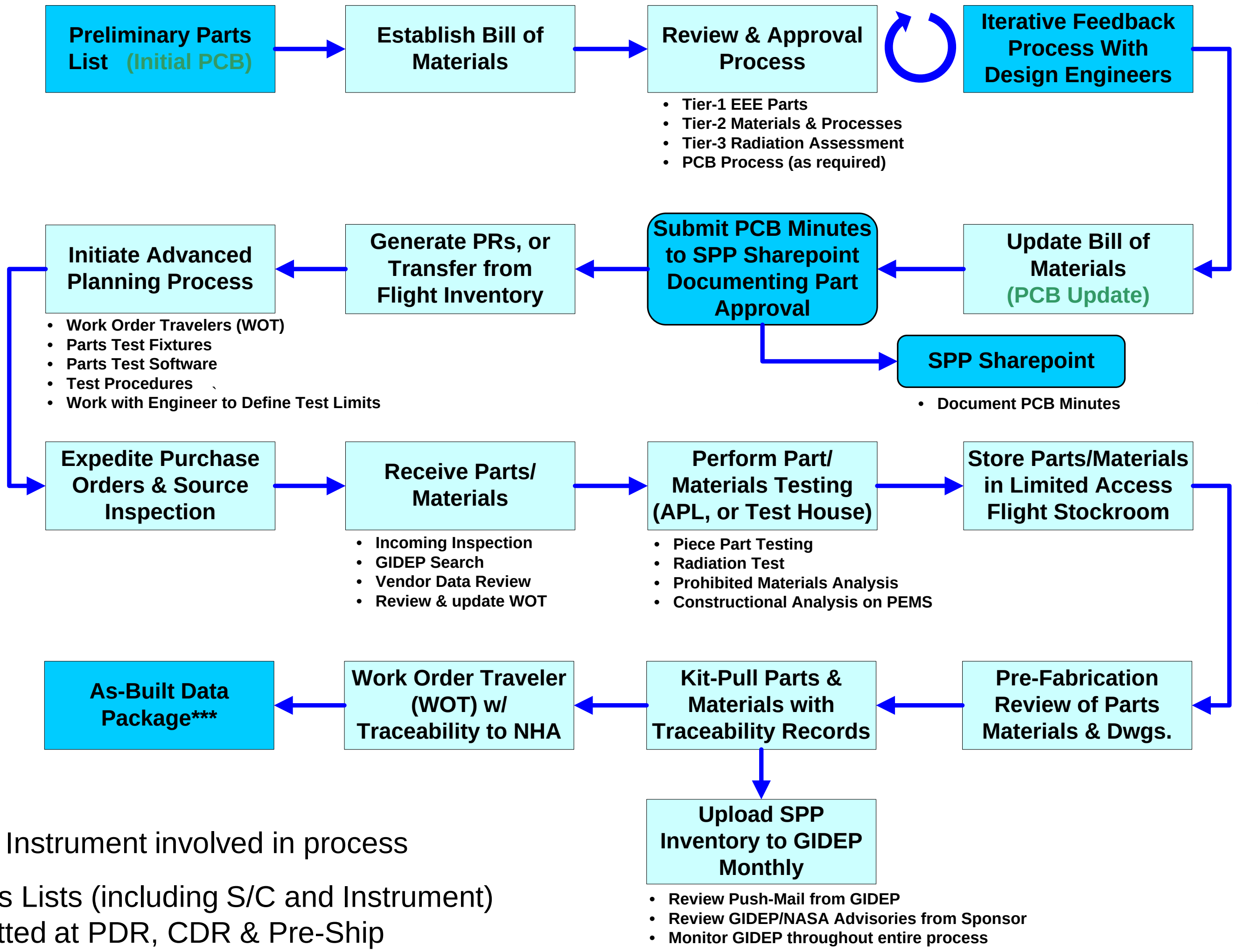
- **Requirements Summary**
  - **Parts Screening/Qualification**
    - **Parts control per 7434-9001, SPP Parts Control Plan**
    - **Parts screening/qualification per EEE-INST-002, Level 2**
  - **Parts Control Board (PCB)**
    - **Participants**
      - **PMPCB Chair, Lead APL Component Engineer**
      - **Mission System Engineer, MSE**
      - **System Assurance Manager, SAM**
      - **GSFC Project Parts Engineer (PPE)**
      - **Radiation, Design Engineers, and SME's as required**

EEE Parts Requirements Continued

- GIDEP Alerts & NASA Advisories Reviewed
  - Each new or transferred lot
  - Inventory database uploaded to GIDEP quarterly
  - Alerts submitted by sponsor reviewed
- Stress Analysis Sheets Reviewed
  - Derating per EEE-INST-002
    - PEM-INST-001 for PEM devices
- Piece Part Traceability & Data Maintained
  - As-Built Parts List

EEE Parts Process



= S/C & Instrument involved in process

***Formal Parts Lists (including S/C and Instrument) submitted at PDR, CDR & Pre-Ship

Parts Control Board Process

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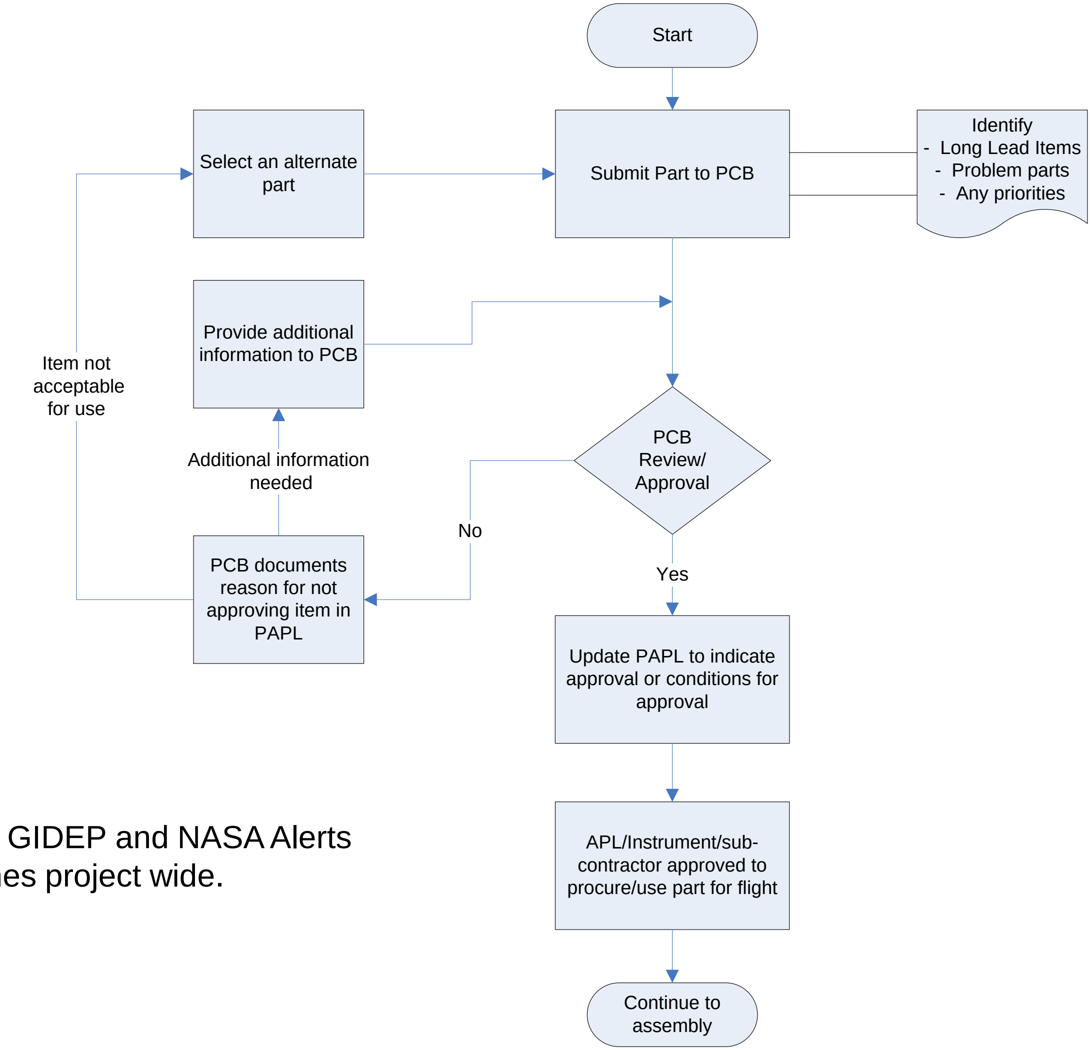


Note: APL is performing GIDEP and NASA Alerts Advisories searches project wide.

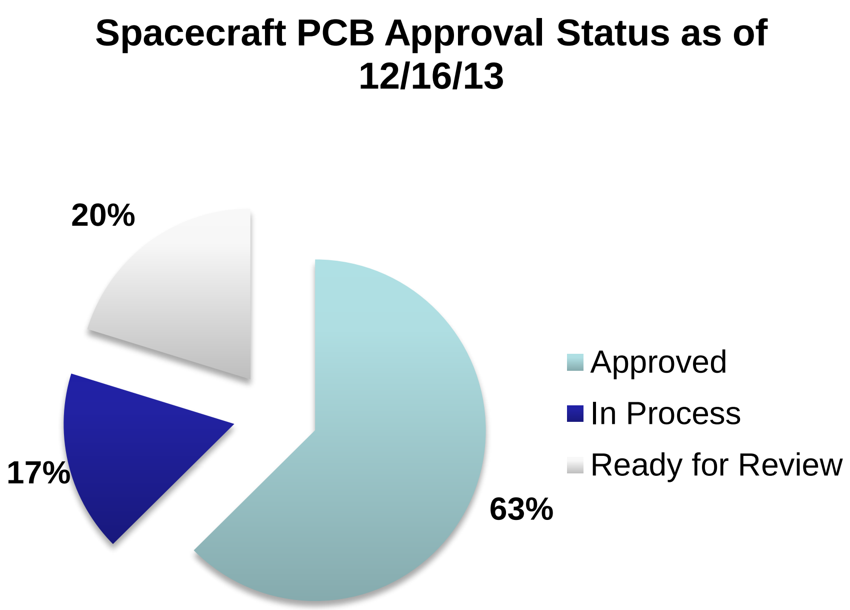
Parts Engineering Phase B Status

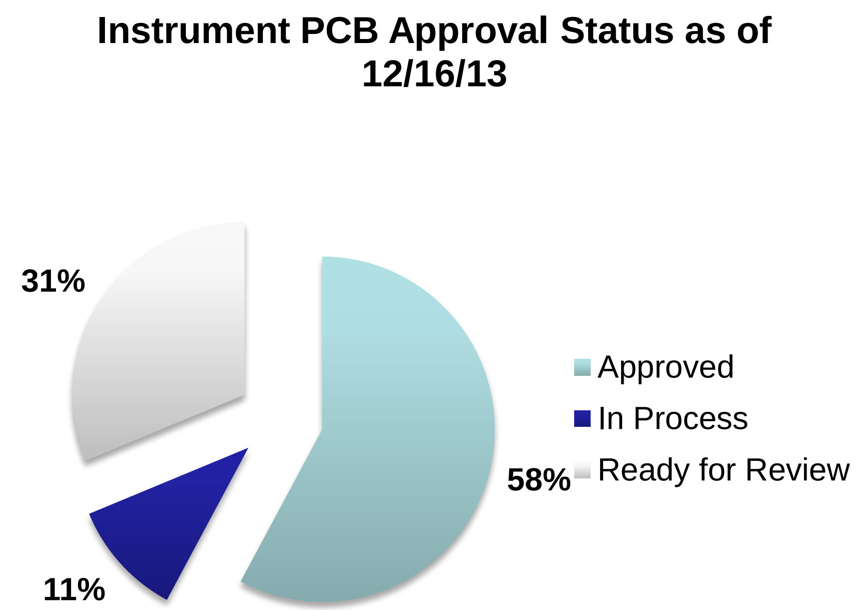
- **Solar Probe Plus Parts Control Plan 7434-9001 (CDRL Item)**
  - **- Revision “A” released into PLM, April 2013**

- **Preliminary Parts Identification List (PIL) 7434-9001-01 (CDRL Item)**
  - **- Revision “-” released into PLM, November 2013**

- **Parts Control Board (PCB) meetings held as both In-person meetings and virtual meetings (via E-mail)**
  - **Minutes are stored on SPP Sharepoint.**

Parts Engineering Phase B Status





- **On Track for Phase B**
  - **Difficult or Long Lead items identified and in process.**
  - **Performed on-site assessment of test houses and selected suppliers whose capabilities closely aligned with the types of parts to be tested.**
  - **Significant EEE parts carry-over from Van Allen Probes.**

EEE Parts Considerations

- **“Coordinated Buy” Candidates**
  - **Parts supplied to both Spacecraft and Instruments**
    - RTAX4000/RTAX2000’s (DLA versions in CCGA packages)
    - Magnetic RAMs
    - LVDS Drivers/Receivers
    - High Voltage Optocoupler
- **Long-lead Items**
  - Rad Hard MOSFETS
  - DC/DC Converters
  - LDO Regulators
  - Oscillators
  - Some relays and diodes
  - Custom Devices (i.e. ASICs, diplexers, splitters and low phase oscillators)
  - PEMs
- **Waivers/Deviations**
  - OP262 derating for FIELDS
  - SIDECAR ASIC for FIELDS

Component Engineering Phase C Plans

- **Begin Procurement of Long Leadtime Parts**
  - **FPGAs**
  - **MOSFETs**
- **Generate Screening and Qualification Plans**
- **Continue Approving Parts in PCB Meetings**
- **Generate As-Designed Parts List**

Conclusion

- **Parts Control Plan signed and released.**
- **PCB is working to review and approve EEE parts.**
- **Ready to begin processing flight lots.**
- **GIDEP monitoring is in place and active.**
- **Parts Engineering is ready to proceed into Phase C.**

Solar Probe Plus

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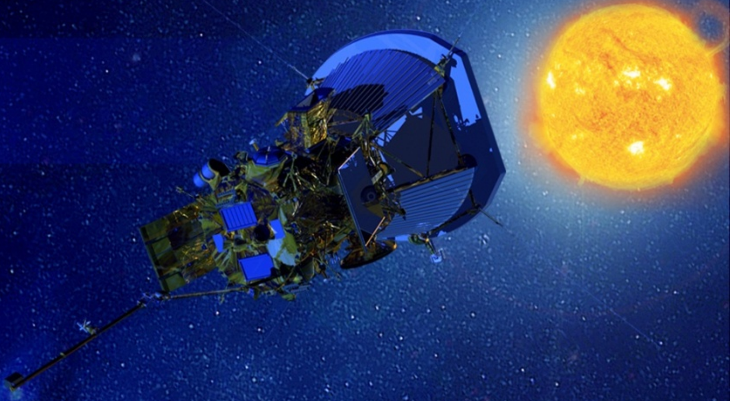


Materials and Processes

Tyler Langley
Lead Materials and Processes Engineer

tyler.langley@jhuapl.edu

13 – 16 January 2014

The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Overview

- **Materials and Processes Requirements**
- **Materials Identification Lists (MIL)**
- **Spacecraft Zones**
- **Phase B Status**
- **Phase C Plans**

Materials & Processes Control Plan

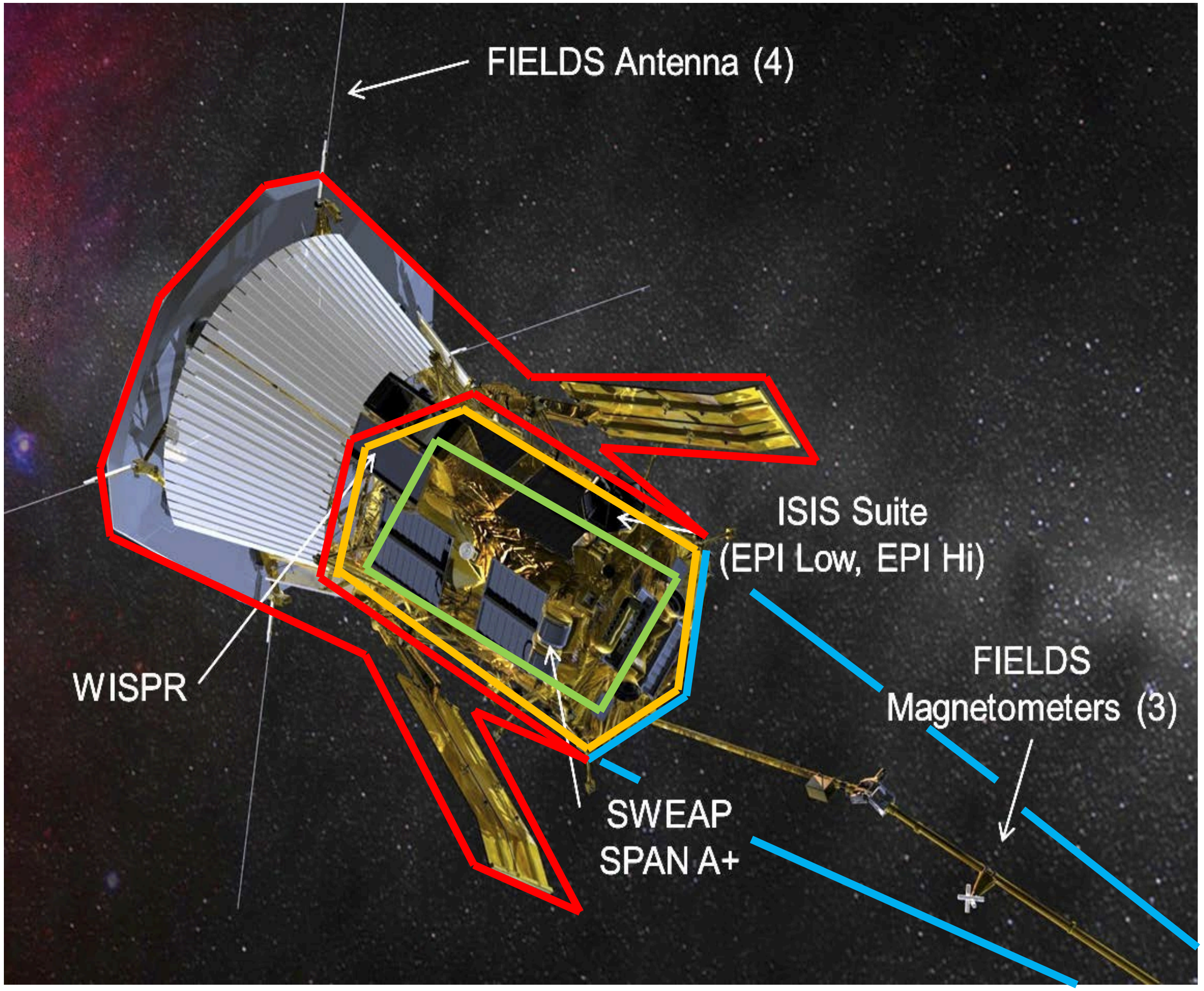
- **Requirement derived from *Solar Probe Plus Performance Assurance Implementation Plan (7434-9003)***
- **Materials and Processes Control Board (MPCB)**
  - **Chair - Lead Materials and Processes Engineer**
  - **Mission System Engineer**
  - **Mission Systems Assurance Manager**
  - **GSFC Materials Assurance Engineer**
  - **Project Contamination Engineer as required**
  - **Project Radiation Engineer as required**
  - **Electromagnetic Environment Engineer as required**
  - **Other subject matter experts invited as required**
- **Materials and processes submittals and approvals are tracked in the Materials Identification Lists (MIL)**
- **Minutes are generated from the MIL and stored on the SPP Website with approvals and/or action items**
- **Review and Track GIDEP Alerts & NASA Advisories**

Materials Identification Lists

- **Single list where materials, radiation, surface charging and magnetic concerns are tracked and approved.**
- **Materials and Processes Categories:**
  - **Metals**
  - **Nonmetals**
  - **Fasteners**
  - **Lubricants**
  - **Processes**
- **The spacecraft has been divided into four zones to facilitate materials approvals.**
- **Current approval status as of December 2013:**

System	Submitted	Approved	% Approved
Spacecraft Bus	194	184	95%
ISIS	229	157	69%
WISPR	179	127	71%
FIELDS	203	MPCB JAN14	-
SWEAP	242	MPCB JAN14	-

Spacecraft Zones



- **A - Inner –Typical spacecraft materials (Outgassing, SCC, etc.)**
- **B - Outer Surfaces – Higher radiation, thermal environment, thermal and optical surfaces**
- **C - Magnetic – Nonmagnetic Materials (Magnetic materials are minimized outside of this zone)**
- **D - Thermal – Survival Temperature ≥ +100C**

SPP Phase B Status

- **SPP Materials and Processes Control Plan 7434-9009**
  - **Revision A released June 2013**
- **Preliminary Materials Identification List (MIL) 7434-9009-01**
  - **Baseline Revision Released November 2013**
- **Long Lead Procurements**
  - **No long lead raw material purchases**
  - **Working with other subsystem leads on major procurements**
- **MPCBs are being held approximately monthly**
- **Materials Testing**
  - **Solar Array Materials Radiation Testing**
  - **Elevated Temperature Outgassing Testing**
- **Currently there are no Materials Usage Agreements (MUA)**

SPP Phase C Plans

- **Raw Materials Procurements to begin**
- **Additional Radiation characterization testing to be performed**
- **Continue to conduct frequent MPCB Meetings**
- **As-Designed Materials and Processes List (7434-9009-02) will be generated (Submitted 60 days prior to CDR)**
- **As-Built Materials and Processes List (7434-9009-03)will be started (Submitted with End Item Data Package)**
- **Materials and Processes is Ready for Phase C**

Backup

Backup - Prohibited Materials

- **Cadmium, selenium, zinc, un-plated brass (copper-zinc alloy).**
- **Pure Tin (<3% Pb), Electrodeposited tin plating (e.g., MIL-T-10727 Type I and ASTM B 545) or hot-dipped tin plating (e.g., MIL-T-10727 Type II).**
- **Mercury and its salts.**
- **One-part RTV silicone sealants/adhesives that cure by reaction with atmospheric moisture to release acetic acid.**
- **With the exception of polyvinylidene fluoride (Kynar), plasticized polyvinyl polymers may not be used; e.g., polyvinyl chloride (PVC).**
- **Hookup wire with insulation made from polytetrafluororethylene (PTFE), fluorinated ethylene-propylene (FEP), and other cold flow-susceptible fluorocarbons.**