

MISSION AND PROGRAM INTEGRATION (MAPI) CONTRACT

International Space Station Requirement Verification for Commercial Visiting Vehicles

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TBD

This presentation is intended solely for the audience to which it is directed.



Agenda



- Background on the ISS and Visiting Vehicles
- Overview of the Commercial Orbital Transportation Services (COTS) Program
- Integrating Commercial Visiting Vehicles to ISS
- Commercial Requirement Verification and Compliance

International Space Station

Program Overview

- Launched in 1998 as a collaboration with the space agencies of the US, Russia, Canada, Japan, and Europe
- Consists of pressurized modules, an external truss and solar arrays, and robotic arms
- Serves as a microgravity and space environment research laboratory in which crew members conduct experiments in biology, physics, astronomy, and meteorology
- Test bed for technology and equipment for future long duration exploration missions to the Moon and Mars
- Maintains a low Earth orbital attitude between 205 and 270 miles
- 6 crewmembers live and work on the ISS
- Currently funded operation through 2024



International Space Station

Visiting Vehicle Resupply

- Requires continuous resupply of food, water, clothing, spare parts, propellant, scientific experiments, and crew
- Currently average approximately 12-14 commercial and government flights per year
- Both manned and unmanned vehicles
- Spacecraft can either dock or be grappled by robotic arm and berthed



Current ISS Visiting Vehicles



Orbital ATK Cygnus



SpaceX Dragon 1



Roscosmos Soyuz



Roscosmos Progress



JAXA HII Transfer Vehicle

Planned and Upgraded Vehicles



Orbital ATK Cygnus 2



Sierra Nevada Dream Chaser



Boeing CST-100 Starliner

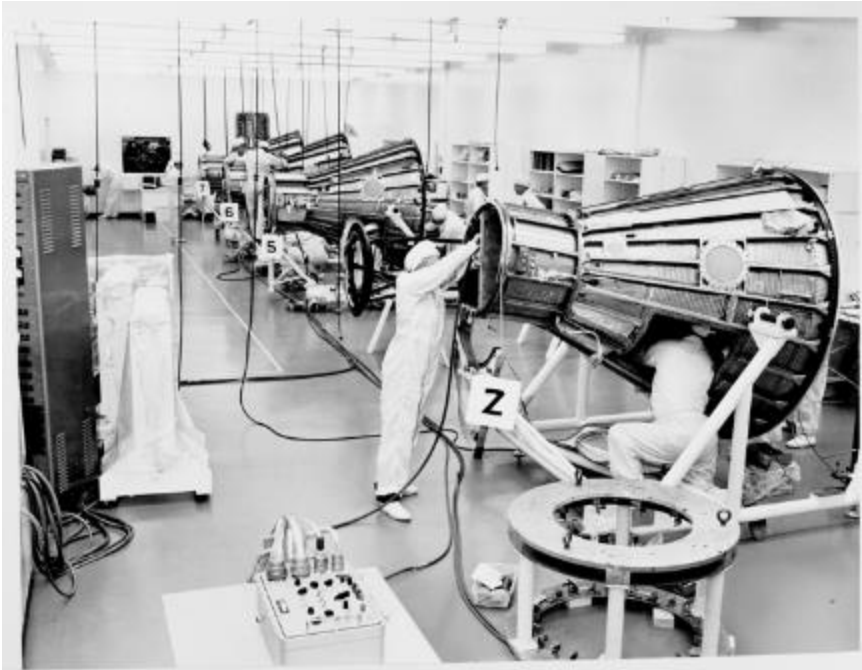


SpaceX Dragon 2 Crew and Cargo Variants



JAXA HTV-X

NASA and Industry



- Since its founding in 1958, NASA has historically focused on government owned and operated space missions
- During the Mercury, Gemini, Apollo, and Space Shuttle programs, NASA has hired contractors to develop launch vehicles and spacecraft
- Contractor operations were subject to heavy government **insight**, defined as NASA's ability to penetrate into vehicle design, development, test, and operations, as well as **oversight**—responsible care and management of contractor activity

Commercial Orbital Transportation Services (COTS) Program



Purpose

- Charged with stimulating commercial enterprise in space by asking US companies to provide innovative, cost-effective commercial cargo and crew transportation to the ISS
- Commercial vehicles intended to take over the task after the planned retirement of the Space Shuttle
- Allowed NASA to focus on Exploration into space and stimulate the private sector to develop and operate safe, reliable, and cost-effective commercial space flight



Commercial Orbital Transportation Services (COTS) Program



Key Concepts



- Change in approach from contractors to **Partners**
- Limited government investment
- Buy a ticket, not a vehicle
- Performance-based, fixed-price milestones
- Non-contract approach to avoid the rigorosness imposed by the Federal Acquisition Regulations (FAR)
 - Space Act Agreement (SAA)

Commercial Orbital Transportation Services (COTS) Program



Implementation

- COTS Program aimed to allow for as much creativity in design as possible without the imposition of detailed specifications
- ISS Program only levied a minimum set of requirements to ensure vehicle compatibility and safety when attached to Station
 - Down from 1000s (Shuttle) to 100s
 - Very few system performance requirements, leaving the commercial Partner responsible for the flow down and verification of most design requirements
 - Partners able to propose alternative requirements/standards
- NASA formed a COTS Advisory Team to provide targeted support and technical expertise to Partners
 - Provided guidance and help without dictating design solutions
 - There were growing pains within the NASA community due to this change in culture

Commercial Orbital Transportation Services (COTS) Program



Outcome

- Resulted in the certification of two commercial cargo visiting vehicles: SpaceX Dragon and Orbital Cygnus
- Following successful certification under COTS, NASA followed the traditional procurement model to purchase services from these Partners under the Commercial Resupply Services (CRS) contracts
 - Having two contracts provided the agency with redundancy in case of slips or mishaps



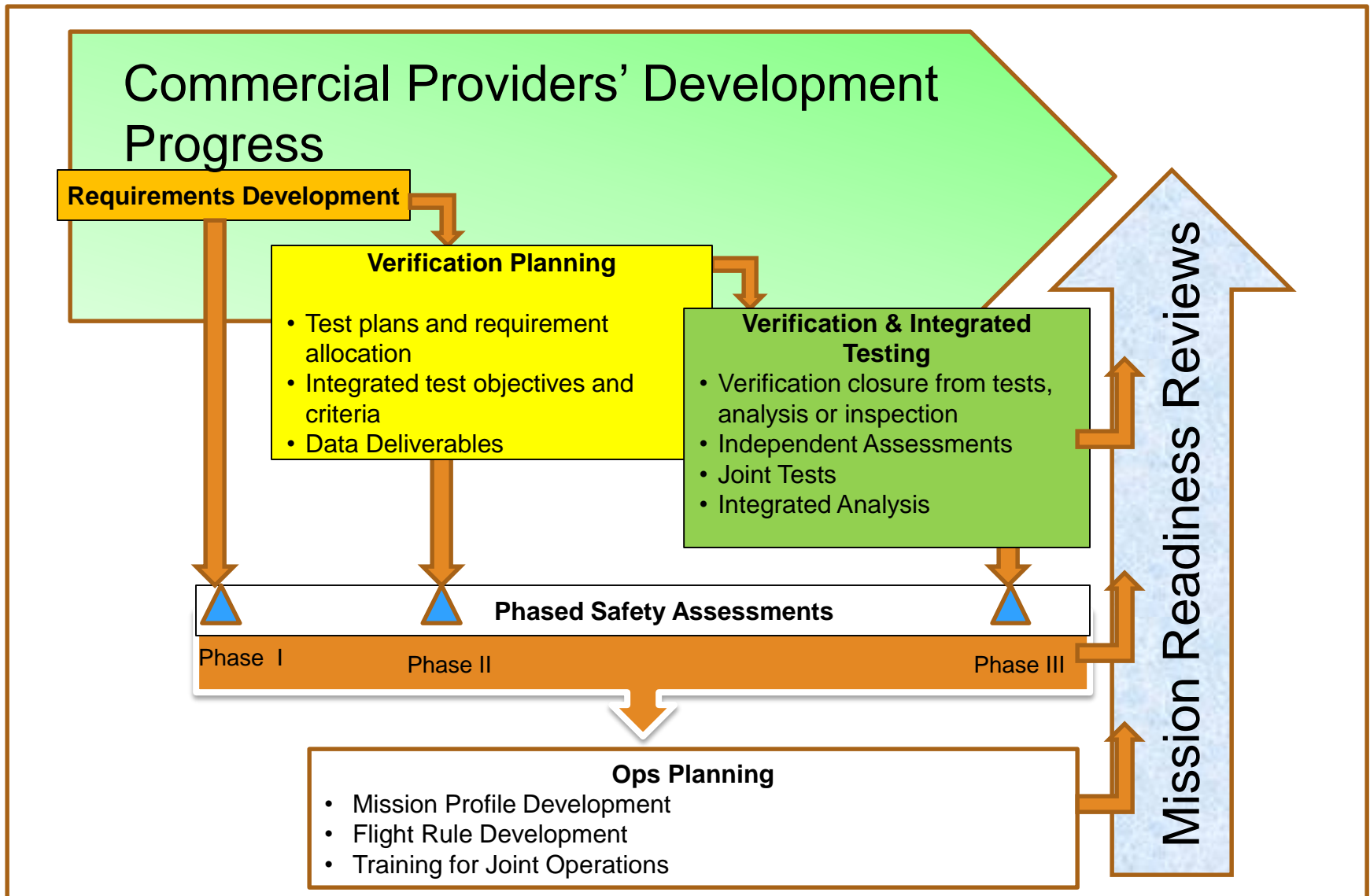
- A similar approach is being followed to develop and certify commercial crew vehicles

Commercial Visiting Vehicle Integration with the International Space Station



- The ISS Program utilizes the following process to ensure commercial visiting vehicles meet the required level of safety and performance to safely dock/berth with the Station
 1. Provide key requirements to the visiting vehicle
 2. Evaluate the commercial providers' compliance to the requirements through their design and production phases
 3. Evaluate final compliance to the requirements through final verification closures and safety assessment processes
 4. Conduct joint testing of key hardware and software interfaces
 5. Perform independent and integrated analysis of the visiting vehicle and the ISS
 6. Ensure there is a sound mission profile and overall joint operations plan

Commercial Visiting Vehicle Integration with the International Space Station



Visiting Vehicle Requirements



- All requirements are documented in a single, generic Interface Requirements Document (IRD)
- Eliminated requirements that did not reduce the risk of ISS operations
- Requirements fall into two general categories:
 1. Ensure visiting vehicle design is capable of berthing/docking with the ISS—**Interface**
 - Ensures compatibility of all interfacing elements, including physical and software interfaces
 2. Protect the ISS structure, equipment, scientific experiments, and crew—**Safety**
 - Two fault tolerance to catastrophic hazards. A catastrophic hazard is any condition that may cause a disabling or fatal personnel injury, or loss of one of the following: an ISS crew vehicle, ISS, or NASA major ground facility
 - One fault tolerance to critical hazards. Any condition which may cause a non-disabling personnel injury; severe occupational illness; loss of a major ISS element, on-orbit life sustaining function or emergency system, or involves damage to an ISS visiting vehicle or a NASA ground facility

Evaluating Design Compliance



- Conduct major technical reviews—System Requirements, Preliminary Design, Critical Design, and Demonstration Readiness per NASA’s Systems Engineering Process outlined in NPR-7123
- NASA assigns a vehicle integration manager to coordinate reviews of subsystems specialists
- Review Item Discrepancy (RID) process allows NASA to review and make comments on design materials
 - Screened by NASA vehicle integration managers to reduce burden on commercial partners
 - Provided NASA sufficient insight to significant development issues

Verification Compliance



- Each IRD requirement maps to a corresponding verification requirement
- The verification requirement indicates a verification methodology (inspection, test, demonstration, or analysis) and success criteria
- Commercial partners develop a Verification and Validation (V&V) Plan that contains:
 - Partner’s requirements and associated verifications
 - Traceability from the Partner’s requirement to the ISS requirement
 - Detailed description of Verification Events (VE) for all verifications traceable to ISS requirements
 - Detailed description of the activities to be performed to complete validation of the vehicle
 - Schedule of V&V activities and products to be delivered to NASA
- Following verification event execution, the partner delivers verification closure documentation in the form of a Verification Closure Notice (VCN)
 - Includes compliance data such as design, analysis, or test reports
- Final verification packages are reviewed and signed off by NASA system experts and the ISS Program

Process Sampling



- NASA negotiates a set of key verification events which must be observed by NASA experts
 - Process sampling limited to critical verification activities and used to ensure that the established verification processes is followed
 - Process sampling also used to establish equivalency to industry, NASA and/or ISS standards
 - Examples of process sampling events include observing the air circulation spot check test, module cleanliness, proximity sensor performance test, capsule leak test, communications system functionality test, and crew interface tests

Joint Verification Events



- Performed by ISS Program with active participation by the Partner and vice-versa when it is determined that more than stand-alone verification activities are necessary to close a requirement
- Verifications that are identified as joint will be captured in a Joint Integration Verification and Test Plan (JIVTP)
- Examples of Joint Tests include:
 - Integrated Software Stage Testing to verifies visiting vehicle flight software system level functionality and compatibility
 - ISS to VV Ground End-to-End Test to demonstrate command/receipt capability from control centers, vehicle, and ISS
 - Common Berthing Mechanism Fit Check/Leak Check
 - Power Quality: Joint test at ISS Power Lab to verify COTS vehicle electrical interfaces
- Examples of Joint Analyses include:
 - Thruster plume loads and heating impact on ISS structure
 - Material outgassing and thruster plume contamination of ISS

Independent Analysis



- NASA performs independent analysis of critical vehicle functions and margins to validate vehicle performance
- Examples include:
 - NASA Rendezvous and Proximity Operations (RPOC) team uses commercial providers' flight software and using an independent simulation evaluates the commercial vehicle's ability to perform Failure Detection and Isolated Recovery (FDIR) and operate per the key requirements
 - NASA and CSA robotic experts perform key integrated assessments of the robotic capture operations
 - NASA teams also conducted independent power and propulsion budget analyses
- To perform this analysis, specific data items are required from the Partner and captured in a Bilateral Data Exchange Agreements List and Schedule (BDEALS)

Mission Planning and Operations



- Pre-flight Planning
 - Operations planning is based on the rule that during joint operations NASA is responsible for the ISS and integrated safety – NASA is lead flight director
 - NASA conducts a series of simulations with the COTS flight control team for each phase of flight to training the crew, develop procedures, simulate anomalies, and check voice and data connectivity
 - NASA uses go/no-go table to determine if the visiting vehicle is in a safe configuration prior to being allowed to approach station
- Flight Operations
 - Selected telemetry from the visiting vehicle is monitored by and used to support go/no-go decisions for each critical phase of flight that could affect integrated operations
 - NASA uses vehicle telemetry to independently confirm parameters for each burn close to ISS

Mission Readiness Reviews



- NASA conducts a series of readiness reviews to ensure requirements are met and the vehicle is ready for launch and ISS integration
 - **Post Qualification Review** identify all outstanding verification items with estimated closure dates and determine whether each item is a constraint to launch
 - **Launch Vehicle Assessment** for new or significantly modified launch vehicles
 - **Stage Operations Readiness Review** to determine whether ISS is ready to accept the visiting vehicle
 - **Flight Readiness Review** conducted by the commercial Partner with NASA participation
 - **Launch Readiness Review** conducted by the commercial Partner with NASA and Range Management participation

Summary



- The COTS program demonstrated NASA could rely on commercial providers for safe, reliable, and cost-effective cargo delivery to ISS
- The ISS Program has developed a streamlined process to safely integrate commercial visiting vehicles and ensure requirements are met
 - Levy a minimum requirement set (down from 1000s to 100s) focusing on the ISS interface and safety, reducing the level of NASA oversight/insight and burden on the commercial Partner
 - Partners provide a detailed verification and validation plan documenting how they will show they've met NASA requirements
 - NASA conducts process sampling to ensure that the established verification processes is being followed
 - NASA participates in joint verification events and analysis for requirements that require both parties verify
 - Verification compliance is approved by NASA and launch readiness certified at mission readiness reviews