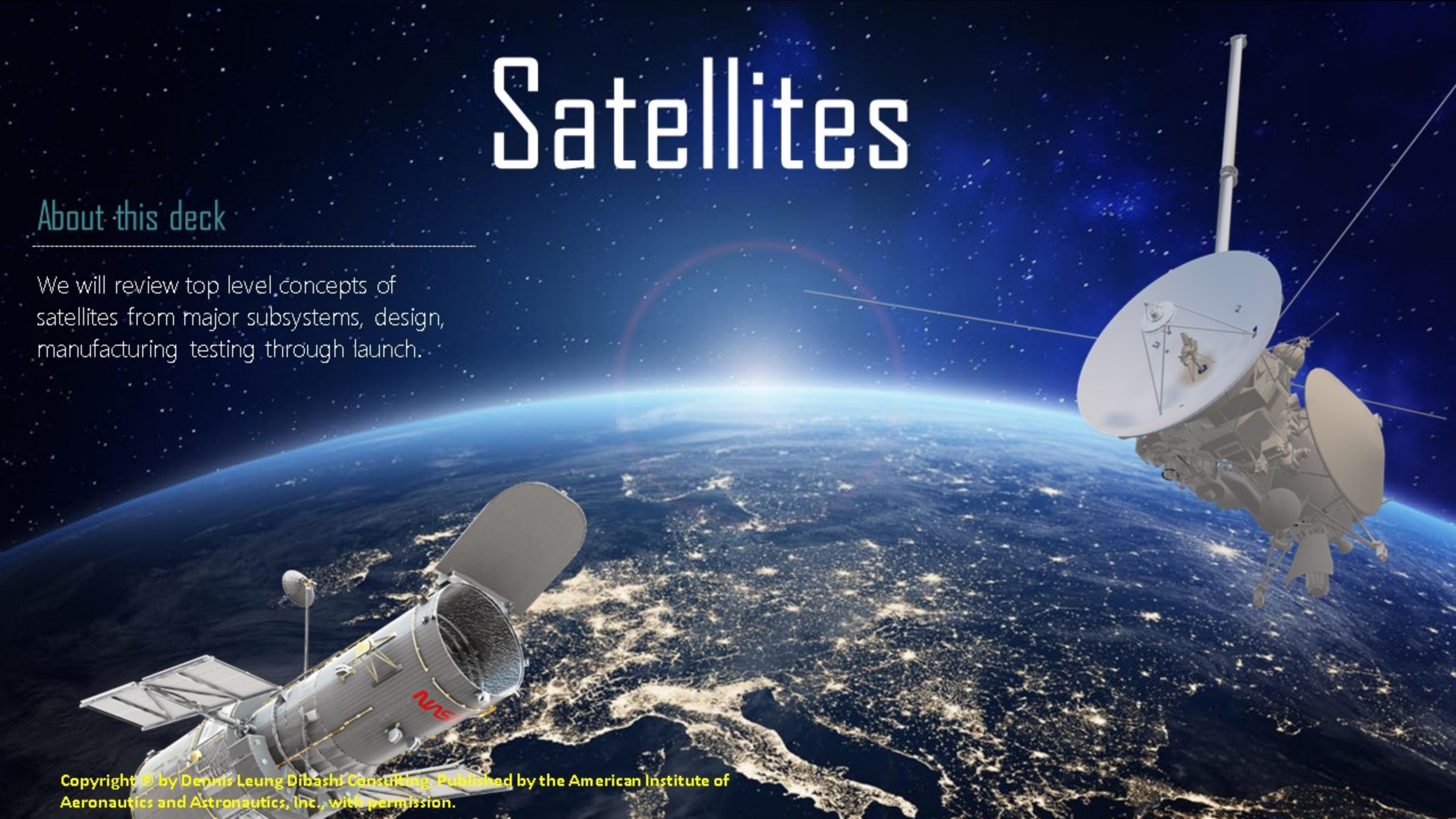
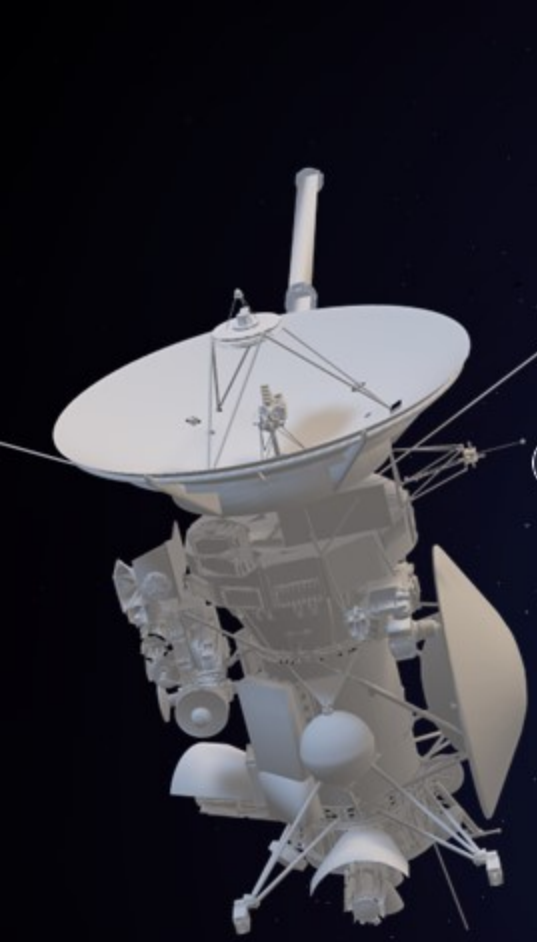
Satellites

About this deck

We will review top level concepts of satellites from major subsystems, design, manufacturing testing through launch.



Power

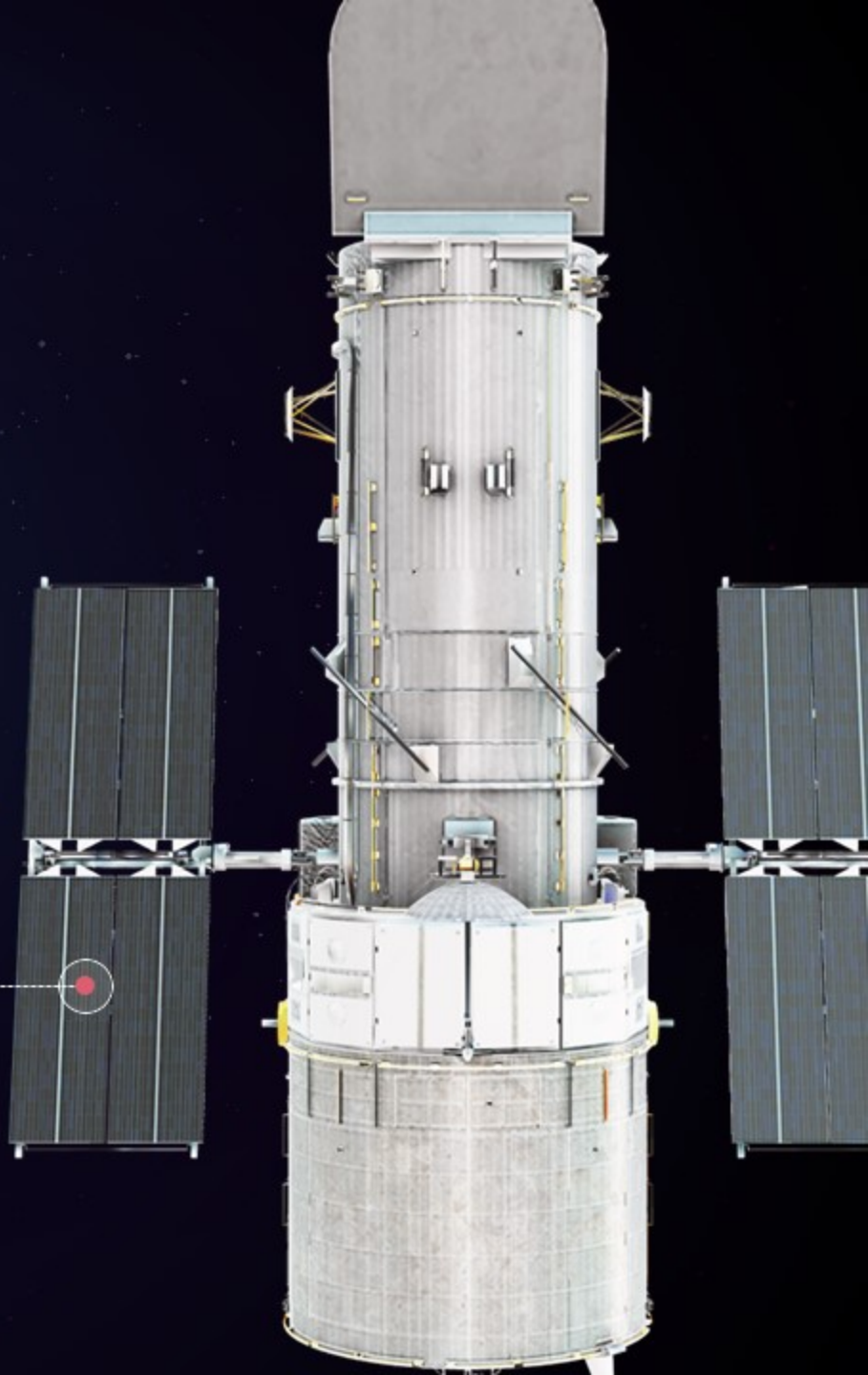


Internal Power

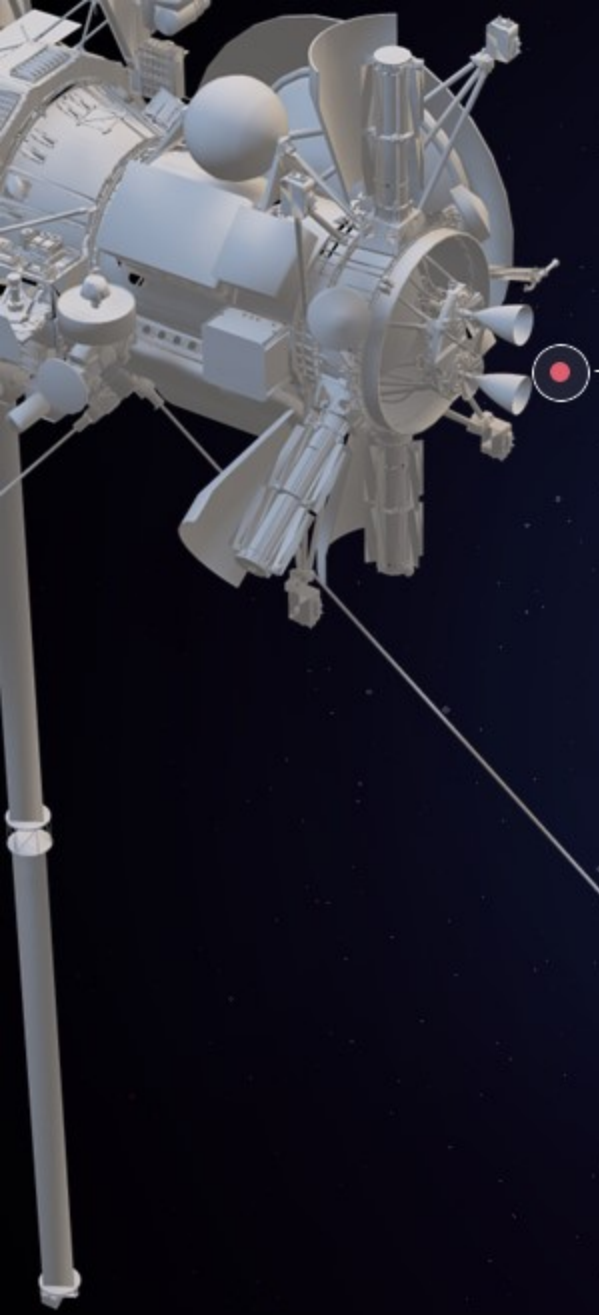
Radio-Isotope Thermoelectric Generators (RTGs) use decay of plutonium to generate heat converting into electricity. Nuclear generators are frowned upon due to the extreme hazardous nature during manufacturing and launch.

SOLAR PANELS

The Hubble telescope is powered by six nickel-hydrogen batteries, which provide power to the spacecraft during orbit while it flies through the Earth's shadow. The scientific instrumentation and onboard computers draw approximately 2800 watts, which are charged by two 2.45 x 7.56m solar panels.



Propulsion



Thrusters

Used for attitude control, orbit insertion and maneuverability. There can be redundancy and multiple independent thrusters with varying force dependent on mission requirements

Propellant Tanks

Different types of fuel systems can be used such as mono-prop or bi-prop. Typical fuel used is hydrazine due to its simplicity in a mono prop system that does not require an oxidizer or secondary tank.

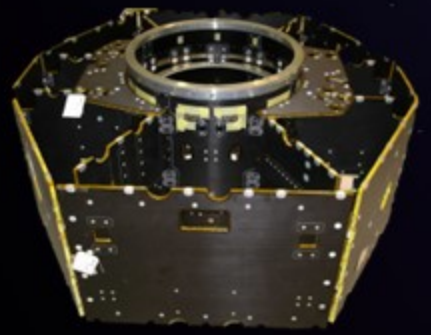
Reaction Wheels

Provides three-axis rotational control without the use of external thrusters.

BUS STRUCTURE

Panels

Internal Bus



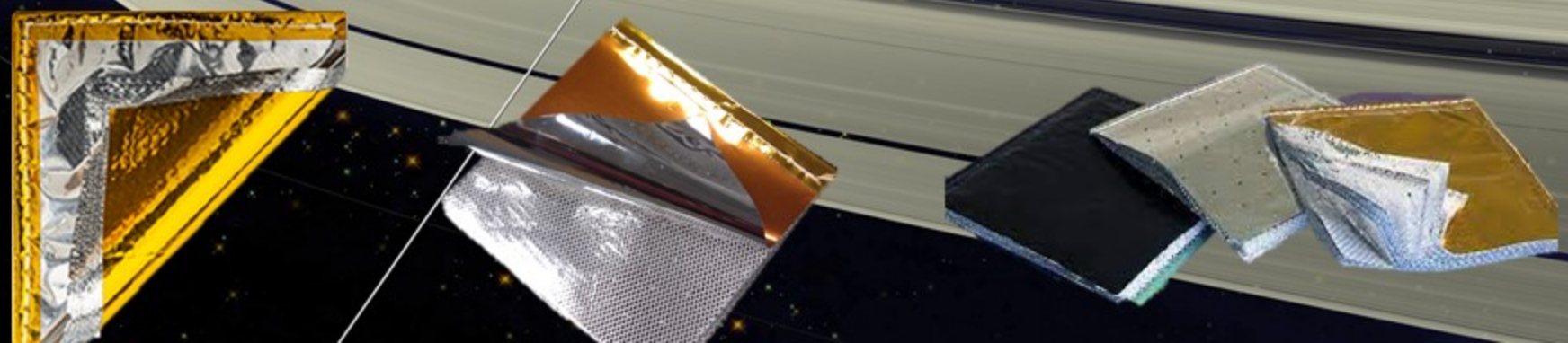
BUS Structure

The Frame of a vehicle which all systems are attached to. These can be made from a variety of material from aluminum to carbon fiber honeycomb composite dependent on mission requirements

MULTI LAYER INSULATION

MLI

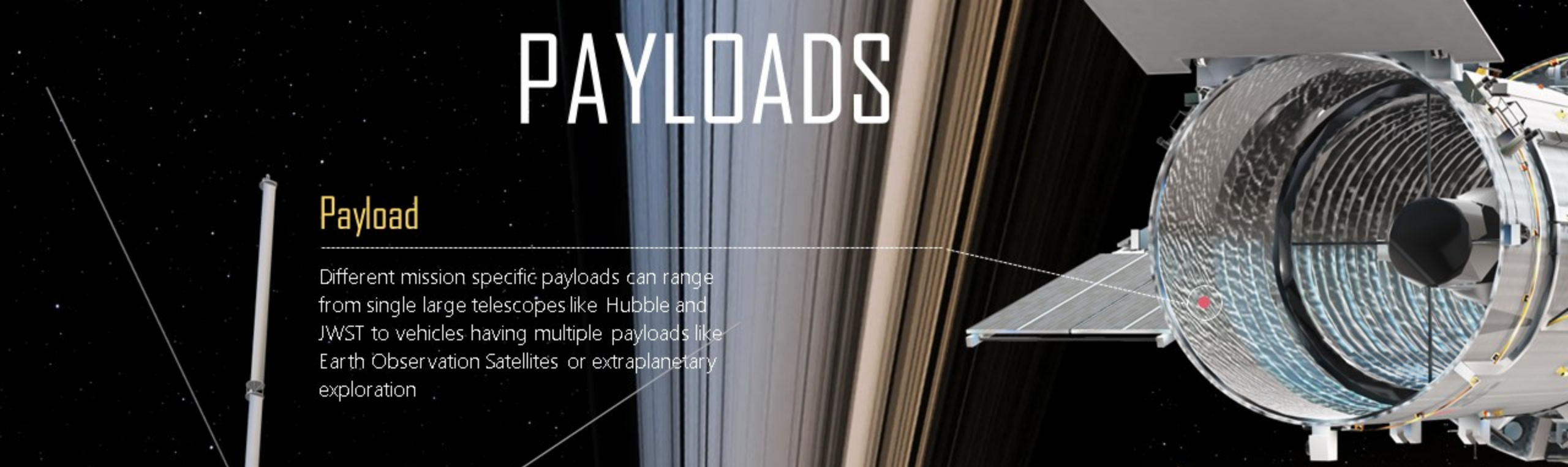
Thermal insulation of a vehicle to keep it protected from the frigid temperatures of space. MLI is made of many different materials determined via mission requirements. Materials can include Aluminized Gold and Black Kapton, Germanium coated Polyimide (does not attenuate radio waves), Stamet coated Kapton (RF Transparency)



PAYLOADS

Payload

Different mission specific payloads can range from single large telescopes like Hubble and JWST to vehicles having multiple payloads like Earth Observation Satellites or extraplanetary exploration

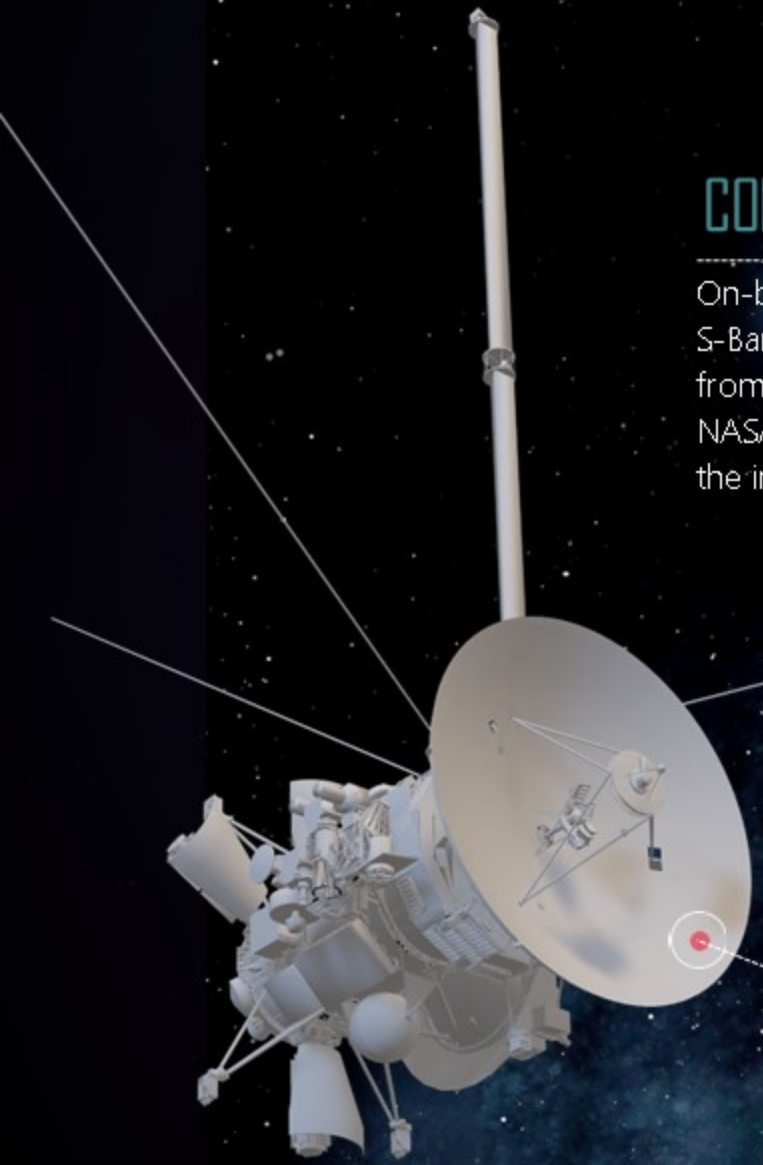


Cassini Payloads

Huygens Probe to drop into Saturn's atmosphere, Cassini Plasma Spectrometer (CAPS), Cosmic Dust Analyzer (CDA), Composite Infrared Spectrometer (CIS), etc.....

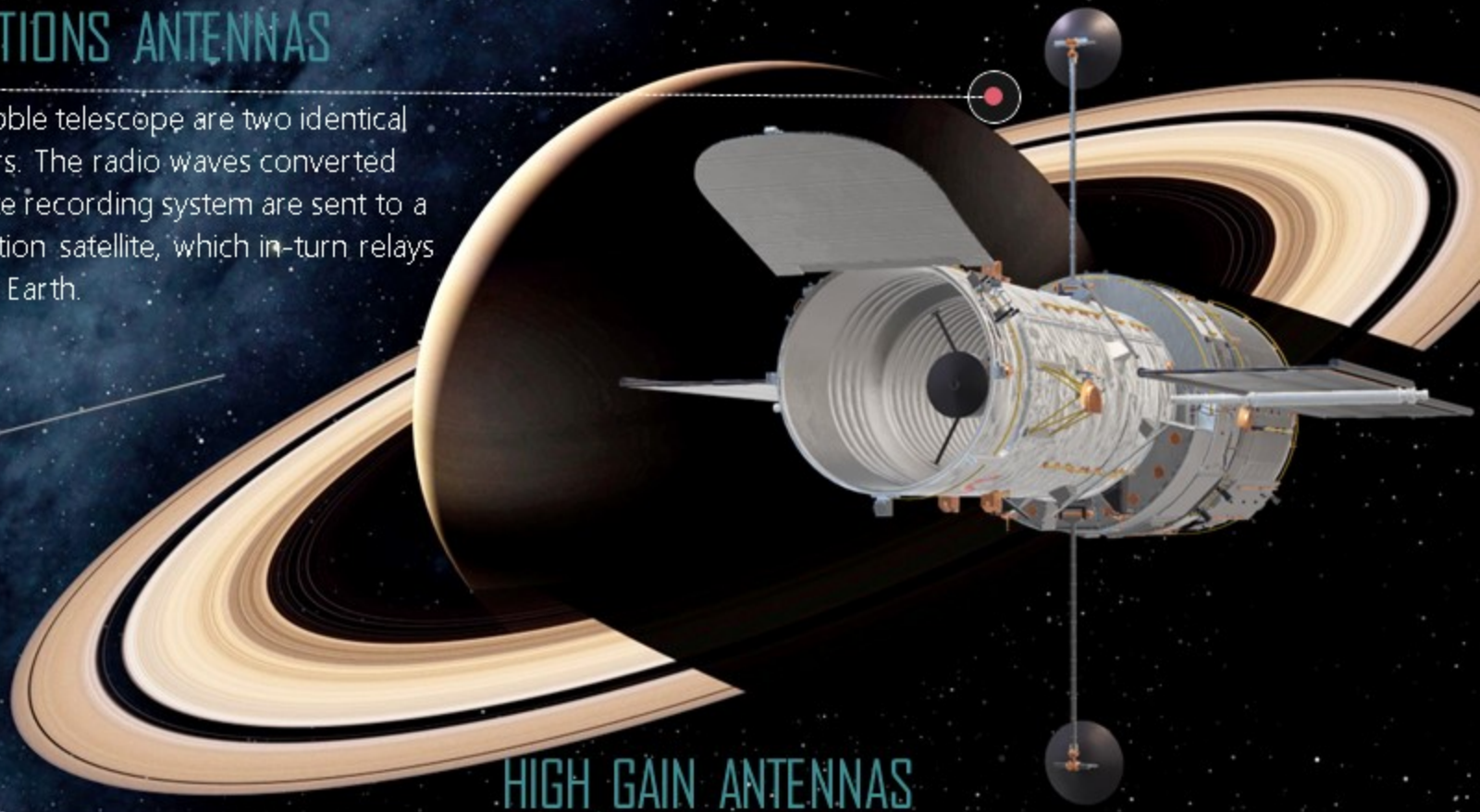
Others like mars exploration has rovers as payloads or Lunar Crater Observation and Sensing Satellite (LCROSS) carried sensor suite payload in addition to the whole satellite being a payload itself crashing into the moon to kickup dust for LRO to observe.

COMMUNICATION



COMMUNICATIONS ANTENNAS

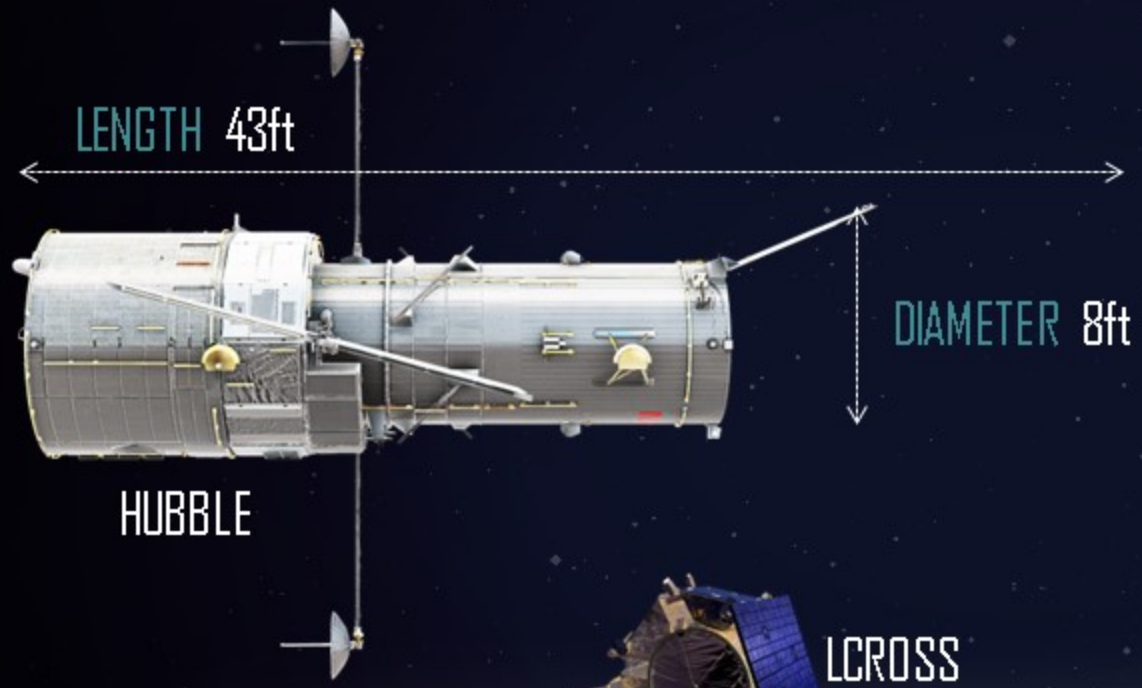
On-board the Hubble telescope are two identical S-Band transmitters. The radio waves converted from the solid-state recording system are sent to a NASA communication satellite, which in-turn relays the information to Earth.



HIGH GAIN ANTENNAS

There are many different types of antennas dependent on the mission scope. Examples include phased array, uplink, downlink, high gain, etc.....

SIZES OF VEHICLES



SUBSYSTEMS

EPS Electronic Power

ACS Attitude Control

COMS Communication

TTC&M Telemetry Tracking Command and Monitoring

GNC Guidance Navigation and Control

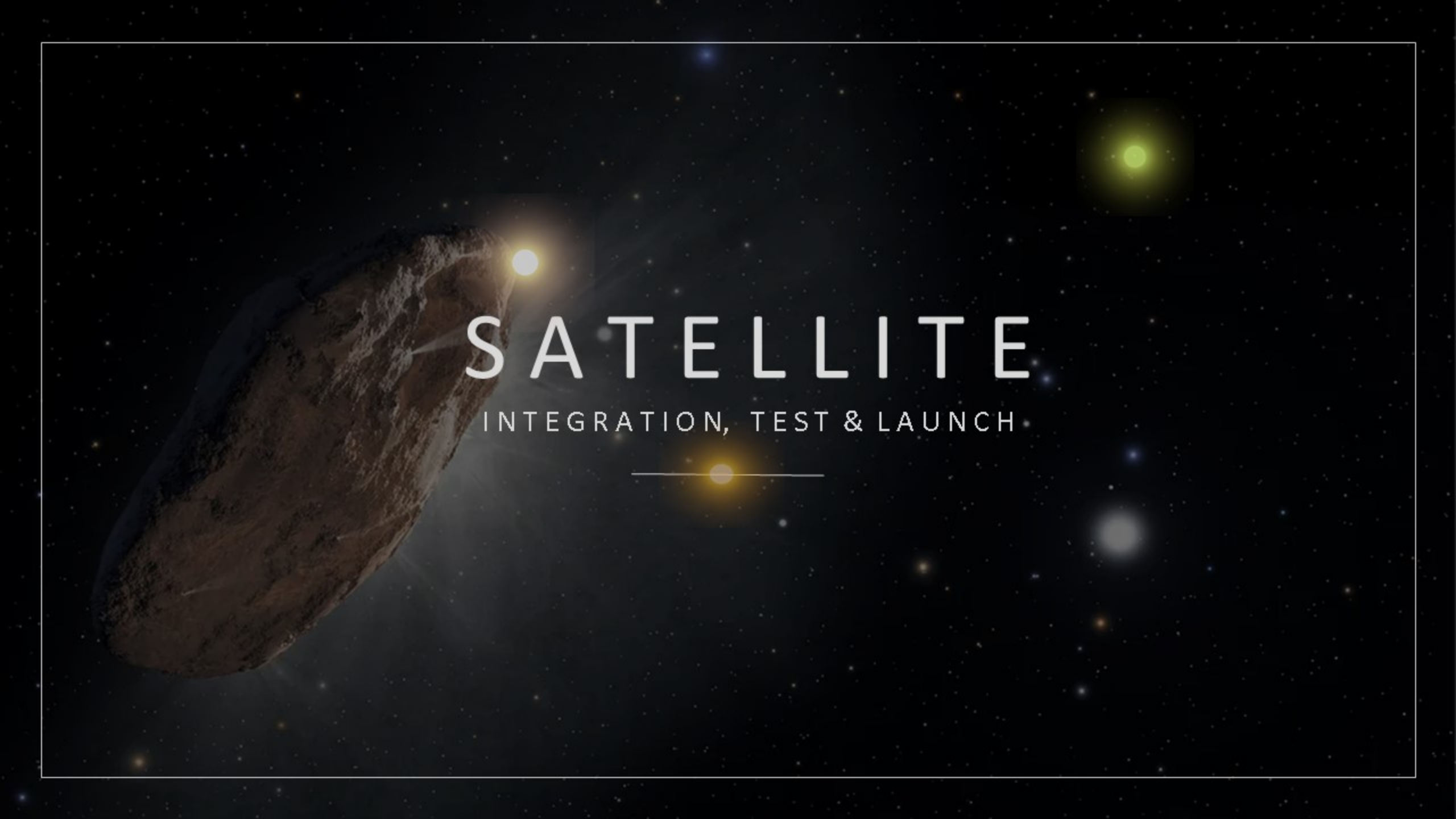
Bus Structure
- Propulsion system
- Reaction wheels
- Electronics
- Batteries

Communications
- Uplink / downlink antennas

Guidance
- Star Trackers

Power
- Solar Arrays

Payloads
- Mission dependent


SATELLITE
INTEGRATION, TEST & LAUNCH

What we do in Integration, Test and Launch

- Installation of piece parts, subcomponent and payloads
- Testing of all piece parts and integrated payloads from subsystem to system level.
- Delivery to launch site and installation onto rocket
- Tracking and monitoring of vehicle until full deployment

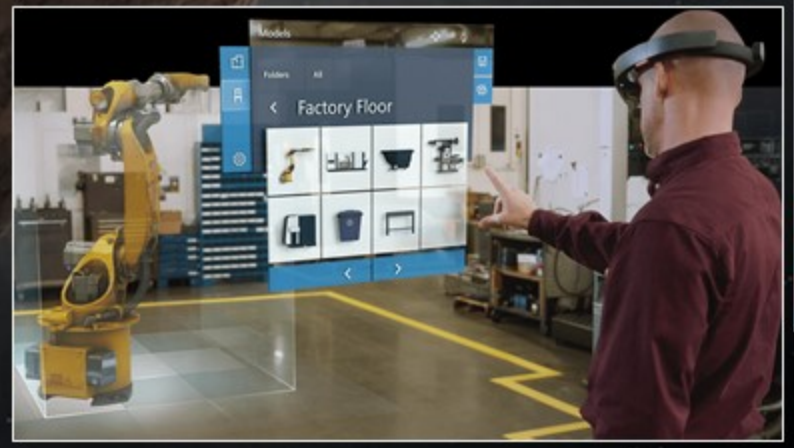
1

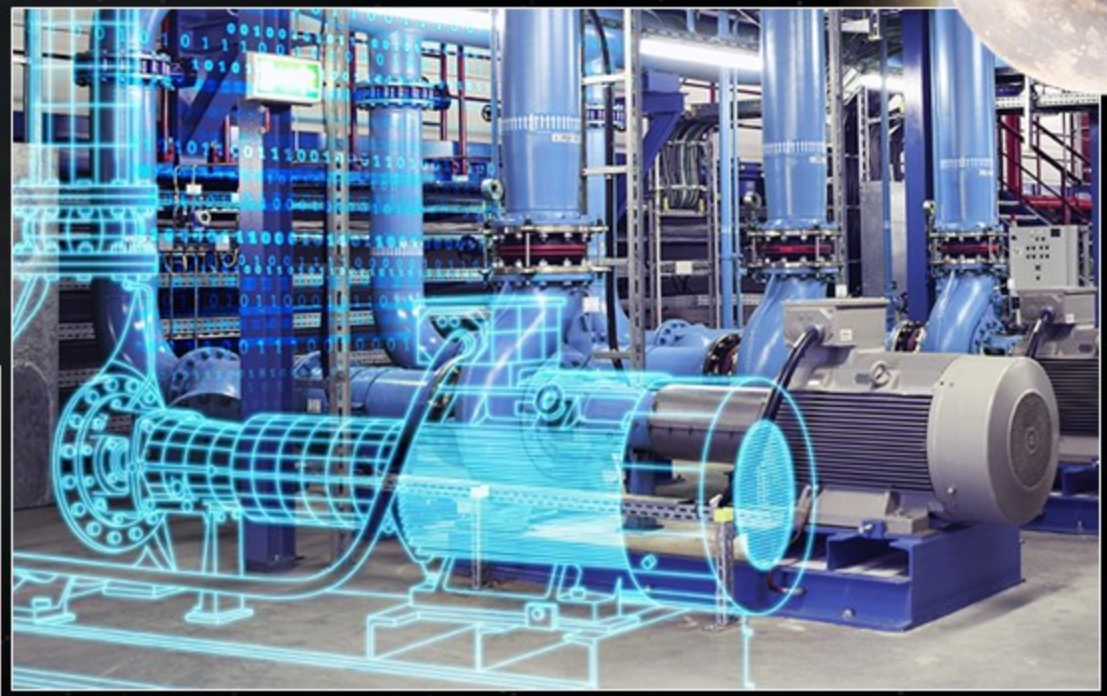
CORE CONCEPTS

A PICTURE IS WORTH A THOUSAND WORDS

Drawings and other visual instructions

- Importance
- Accuracy
- Need to look beyond





Instructions

Integration

Writing step by step instructions based on drawings and process specifications to install hardware

Any supporting operations from logistics to MGSE requires its own set of instructions as well.

Testing

- Instructions based on drawings and process specifications to install/remove hardware onto testing equipment

- Test runs require detailed steps along with actual run data included with the pass fail criteria.

Launch

Logistics especially when different organizations are involved are especially crucial to avoid confusion.

Instructions coordinating with fueling operations, launch provider , red/green tag operations and for encapsulation is the final set of documents to be delivered to customer..

No Work Happens Without Paperwork

The Importance of Instructions and Trust

NOAA-N Prime Satellite

What happened?

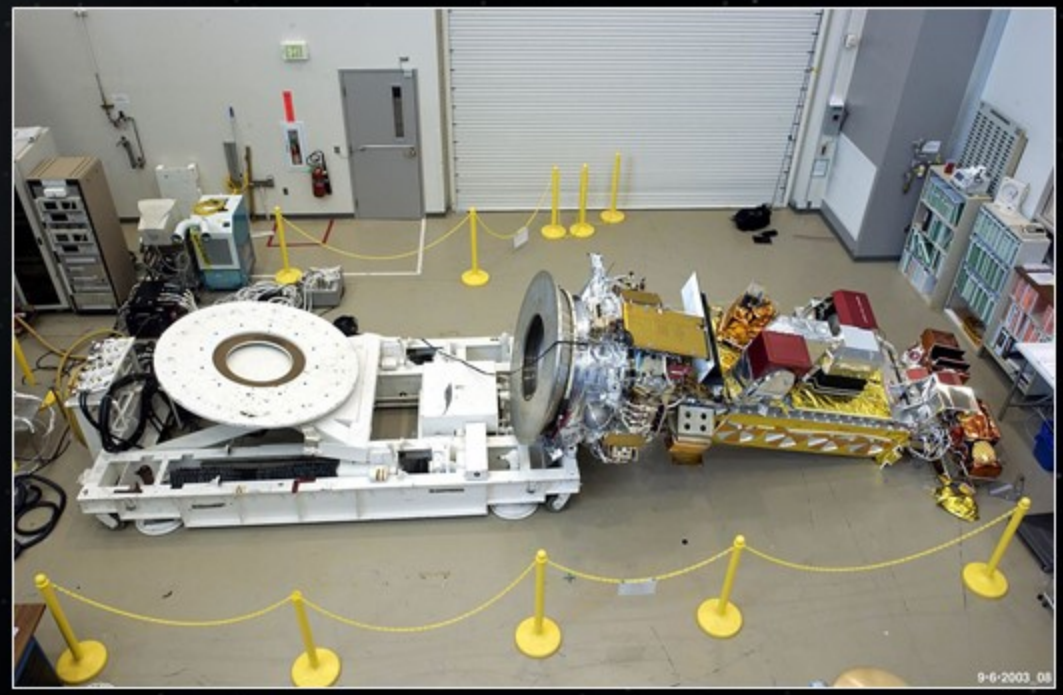
- Workers tipped a $200M weather satellite over for access
- The satellite smashed into the floor, causing $135m damage

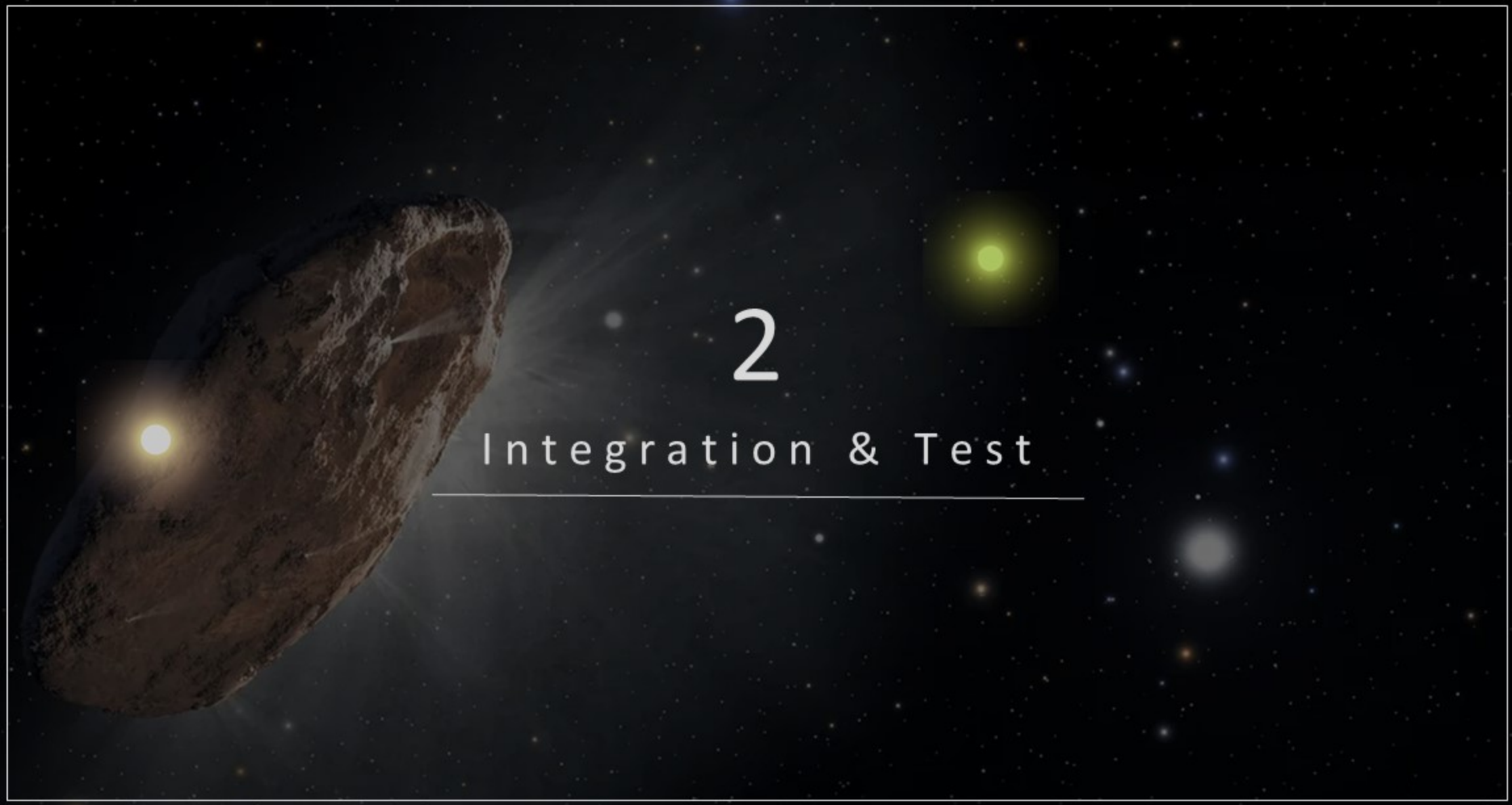
Technical cause identified

- Others had "borrowed" the holding bolts over the weekend
- The rotation procedure required verifying bolts were in place
- Workers violated procedure

Real cause - Culture of inattention

- Characterized by poor communications, failure to correct known problems, and supervisor violations





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Integration & Test

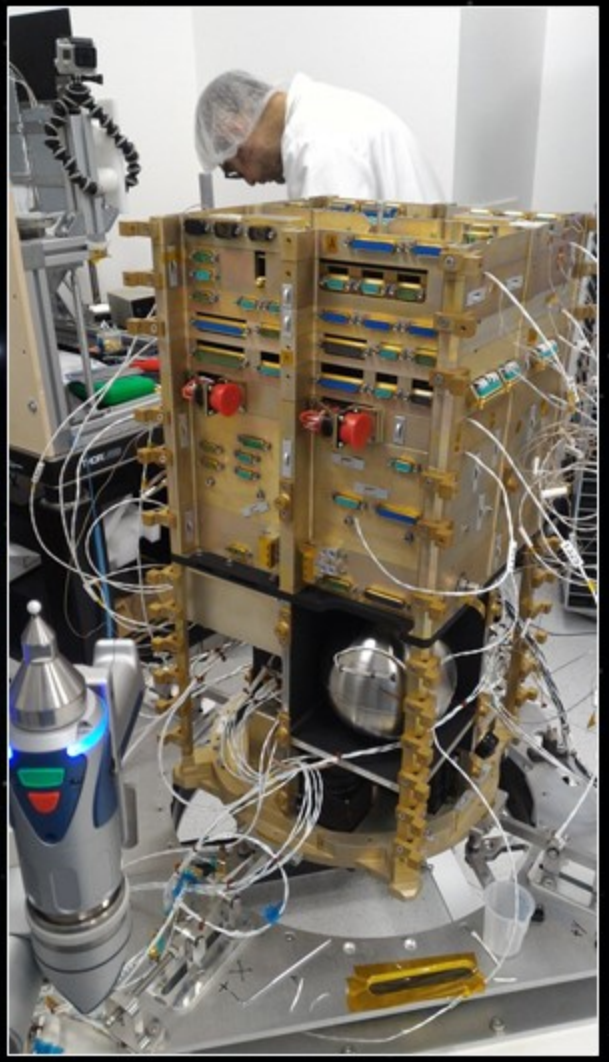
Integration

Piece parts into subsystems

Substems into system level

Flight Software development

High Fidelity Test Beds



High Fidelity Test Bed

Validate System Architecture

- C&DH (Command & Data Handling)
- GN&C (Guidance Navigation & Control)
- EPS (Electrical Power Systems)
- Comm/RF (Communications / Radio Frequency
- Payloads
- Propulsion

Software - Both flight and non flight testing scripts

- Ensure prohibited commands in place
- Ensure database up to date
- Dry run scenarios
  - Fault mgmt test
  - Dry run CPT tests
  - Troubleshooting

Integration

MGSE (Mechanical Ground Support Equipment)

Support stands, offload systems, transportation,

lifting fixtures, etc…

Mechanical / Electrical

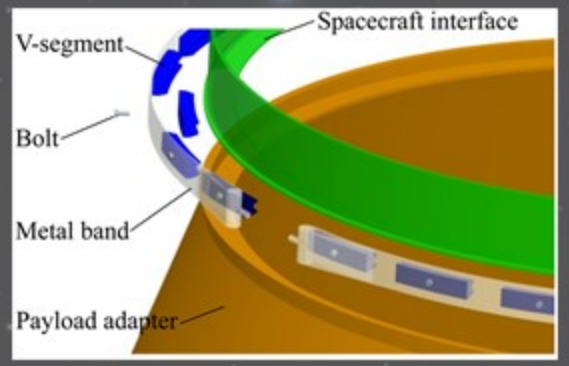
Installation of all mechanical components such as propulsion system, thermal components and harnesses.

Initial testing begins like harness pin checkouts, thermal component aliveness, propulsion system pressurization, software ATS (automated test sequences).

Mechanical / Electrical Testing

What is the purpose?
Verifying basic functionality
Different levels of checkouts
- Piece parts (harness, cables, etc…)
- Subsystems
  - Why are alignments important?
  - Alignments – are the star trackers installed correctly in relation to the bus optical alignment mirrors?
  - Reaction wheels – is polarity correct? Is the RPM correct?

Why do we perform checkouts at different levels before proceeding?
- What can happen if we skip this step?
  - Invalidation
  - Damage
  - Program impact



Mechanical Testing

- Different Tests
  - Propulsion system
  - Solar Panel
  - Deployment
  - Clamp band
  - Alignments
  - Ordnance
  - Reaction wheels

Where do we get the pass / fail criteria?

Why is this important?

MLI (Multi Layer Insulation)

Often missed group but provides a crucial survivability function.

What is MLI and how is it made?

- Sewing
- Thermal welding
- Tape

Why is it important?

- Thermal protection
- Thermal radiation

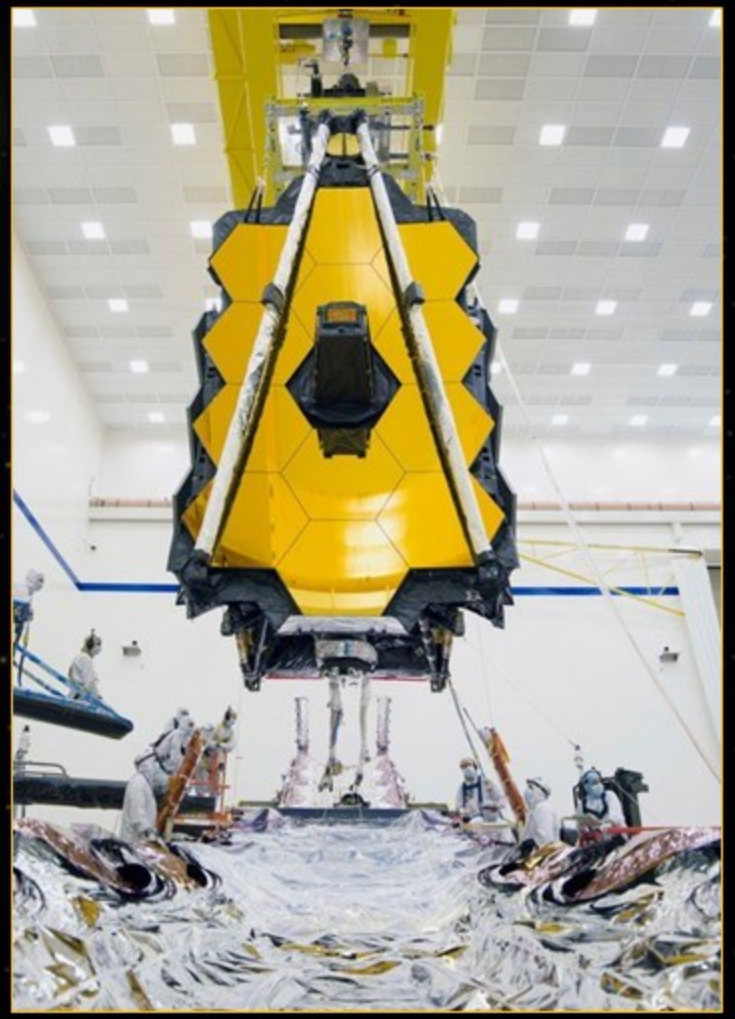
Design features

- Thermal properties based on Thermal Engineering Models
- Air escape system
- Range of motion for deployables

Payload Integration

Payloads can be from subcontractors or built in house. Regardless of who made it there are certain things we must all adhere to.

- SCD (Source Control Drawings)
  - What is the importance?
- Site inspections
  - What is the importance?
- Logistics
  - Why do we care?



Functional / CPT Testing

Definition: validates the hardware/software system against the functional requirements/specifications.

What is the importance?

- Understanding baselines at each level
- Understanding pass / fail criteria during testing

Understanding the complexity of testing mechanical space hardware

Why do we do CPTs?

Verification and Validation of requirements
Baselines definition for pass/fail criteria pre and post environmental testing and delivery.

Fault Management Testing

What is this?
Why do we do this?

3

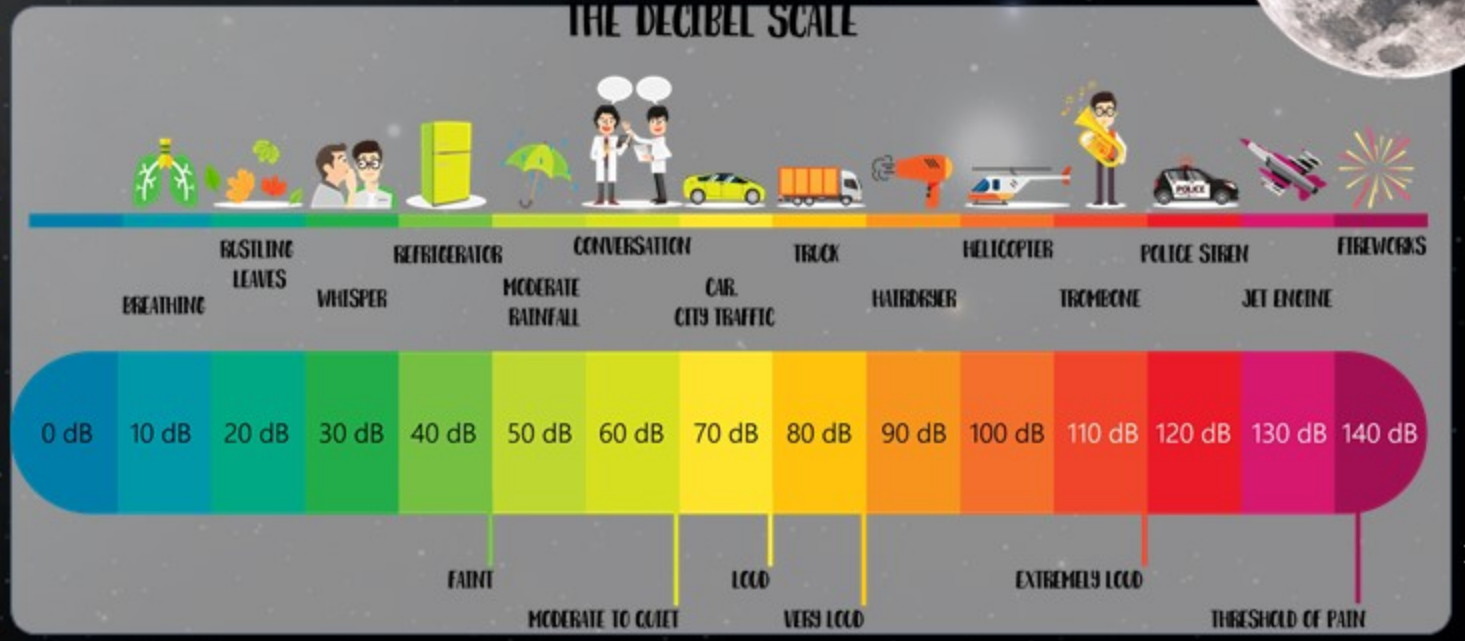
ENVIRONMENTAL TESTING

Dynamics Testing

Spacecraft are subject to intense acoustical environments that induce strong vibration levels into hardware. Dynamics testing of vehicles simulates launch conditions as "close" as possible.

Dynamics Testing:

- Acoustics
  - The launch decibel levels (>180) are high enough to damage hardware
- Vibe
  - The thrust oscillations from a rocket produces vibrations like a paint shaker

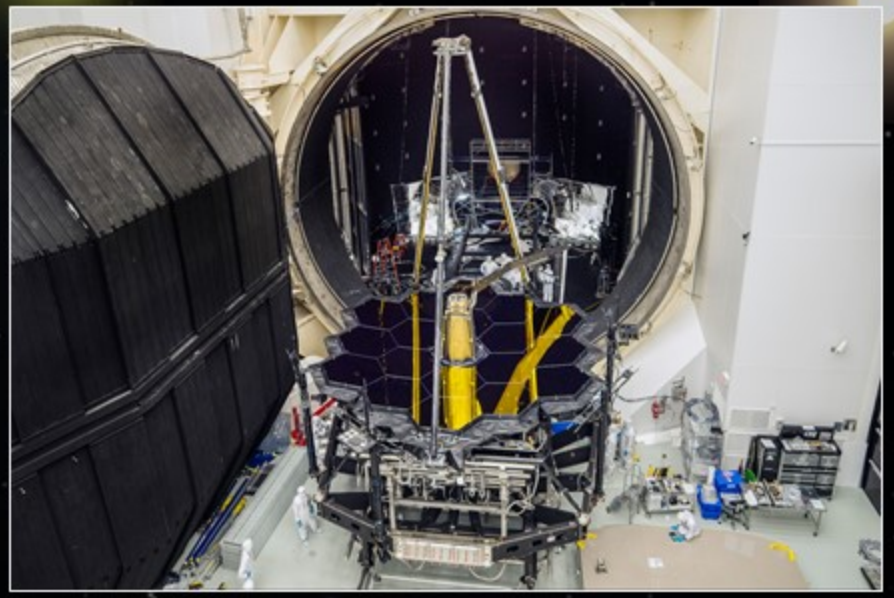


Thermal Vacuum Testing

Spacecraft are subject to intense thermal environments in space. Thermal testing of vehicles simulates operating conditions as "close" as possible.

Thermal Testing

- TVAC (Thermal Vacuum)
  - Dependent of orbit, temperature can fluctuate from >248F or >120C on dayside and plummets to -148F or -100C in the shade.
- Prohibited materials
  - Tin, Cadmium plating and Zinc are subject to spontaneous whiskering causing short circuits.
- Thermal Cycle



EMI / EMC Testing

Electromagnetic Interference/compatibility

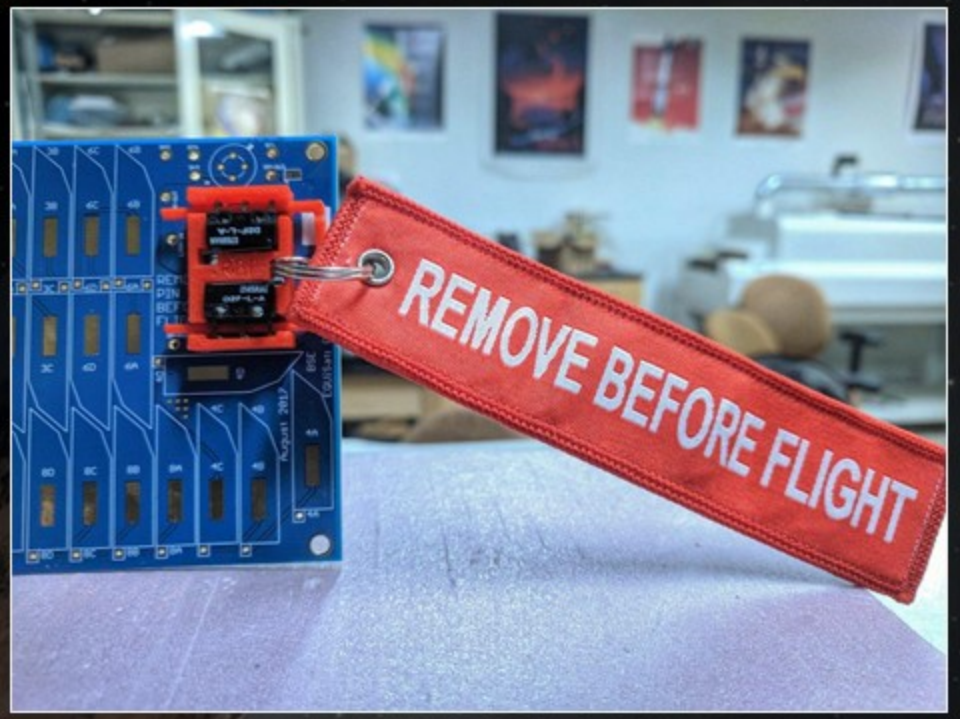
It is essential that all electrical and electronic components in a spacecraft function properly when everything is turned on.

All electrical components have emissions of some sort that can cause interference with other components/systems. This is where items are shielded

4

FINAL PREPS & CONTAINERIZATION

Final Preps / Containerization



Final tests prior to shipping

Post Environmental CPT

Verification of pre-environmental CPT results.

Final configuration and installation/inventory of red/green tag items for shipment to launch site

Mass properties

Weight and CG (Center of Gravity)

What is the importance?

Containerization

Launch campaign begins

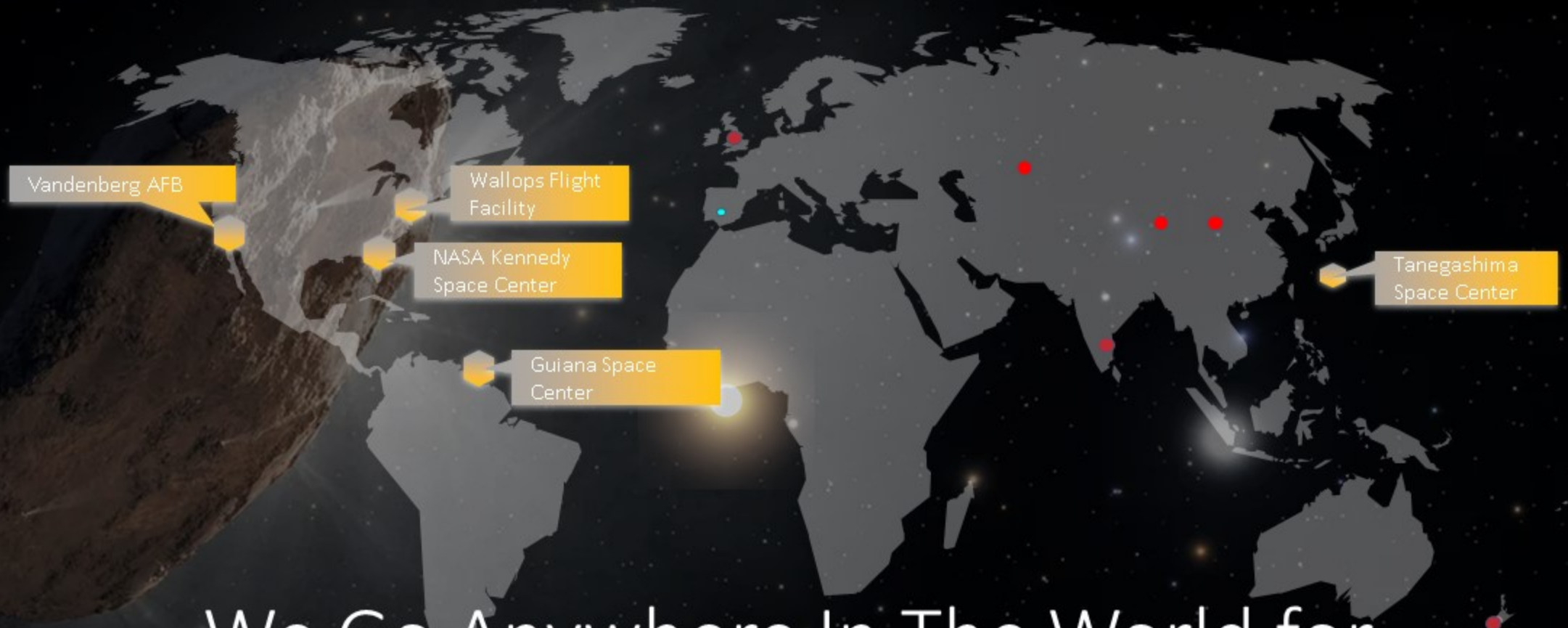
- Break down the factory and move to the launch site!
- Logistics is absolutely critical at this point as many organizations are involved.
  - Transportation plans and routes mapped along with coordination of both state and federal authorities.

All environmental controls and maintenance of container must be detailed out and understood.

5

LAUNCH CAMPAIGN & SHIPPING

Launch facilities



We Go Anywhere In The World for a Launch Campaign

Shipping Logistics

Where are we going?

- Who owns the facility?
- Who is going?
- What is going?
- How long are we going for?
- What are we going to be doing there?

How are we going to get there?

- Has a trailblazer been performed?
- Has transportation been finalized and confirmed?
- Necessary permits and permissions received?

What does the facility have?

- Does it have necessary equipment?
- Does it have the capacity?
- Office space, conference room, storage?

Accommodations?

- Where is everybody staying?
- How long?
- Necessary travel forms approved?
- Transportation?
- Rules of conduct in place?
- Rules of support in place?

Shipping Options

Sea, Air or Land

- Transporting via ship (JWST)
- Air Transport via Air Force C5 Galaxy
- Ground via trucks

Each method above provides their own challenges and unique solutions.

Who provides transport?

8

PAYLOAD PROCESSING

Offsite Setup

Advance teams prepare to receive the vehicle

- Setup high bay and organize to receive vehicle.
- Clean container prior to entry into facility
- Remove container and begin removal of vehicle

Vehicle Processing Operations

Verify no anomalous incidents during delivery and no visual damage occurred.

Perform a powered up systems check out to verify no damage to internal systems.

Begin Red / Green Tag Operations

Install flight clamp band

Prep for fueling operations

Vehicle Fueling Operations

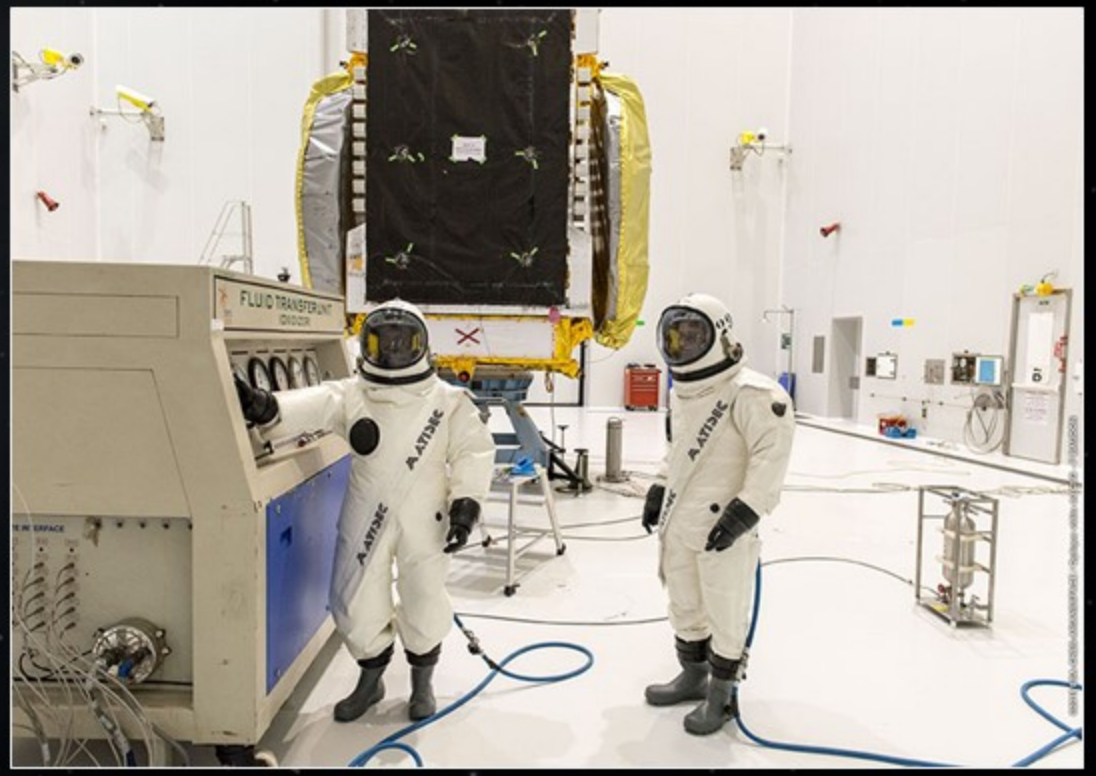
HAZARDOUS Operations!

- Building cleared only essential personnel

Coordination and dry runs with all associated personnel from range safety to technicians

Fueling operations differ from each vehicle dependent of type of propulsion system used. Typical fuel used is Hydrazine which is highly combustible and toxic.

Who is responsible for this operation?



Encapsulation & Transport

Begin encapsulation

- Vehicle is 99% configured at this point
- Rocket providers operation to encapsulate and transport to rocket processing facility

Final operations move from payload processing facility to rocket processing facility

Who is responsible for this operation?

Fairing Lift to Rocket

Payload fairing transported to rocket processing facility and hoisted to the top for mating operations. These operations are performed by the launch provider.

Launch Dry Runs

Control room teams are running launch day rehearsals including “go” “no go” checks while mechanical preps are underway at the rocket processing facility. This is your last chance to resolve any remaining issues.

Final Vehicle Operations on Pad

Final Red / Green Tag operations are underway.

- Ordnance engineers are removing the non-flight IFJ (in flight Jumpers) which are used to prevent an accidental initiation of separation sequence from the rocket clamp band.
- Quality engineers are doing one final inspection and verifying all documents relating to red/green tag operations.
- Final issues and discrepancy and remaining paperwork closed out.
- Rocket provider does final inspection and close out of fairing is started.

9

LAUNCH

Roll Out

Rocket is rolled out to pad and final preparation are underway at the launch pad and in the control rooms.

Launch Day

Mechanical teams are preparing for launch recycle operations in case of launch scrub.

- Teams ready to secure vehicle in case a prolonged delay.
- There can be multiple scrubs down to the seconds

Launch scrubs have major repercussions from both a schedule and technical standpoint.

- Other schedule launches potentially delayed
- Cost Impacts

Post Launch Operations

- Include monitoring in the control rooms for ascent and on orbit checks on the vehicle.
- Separation confirmation and key systems activiation, deployment sequences and final on orbit checkouts which can last months.

Thank You

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