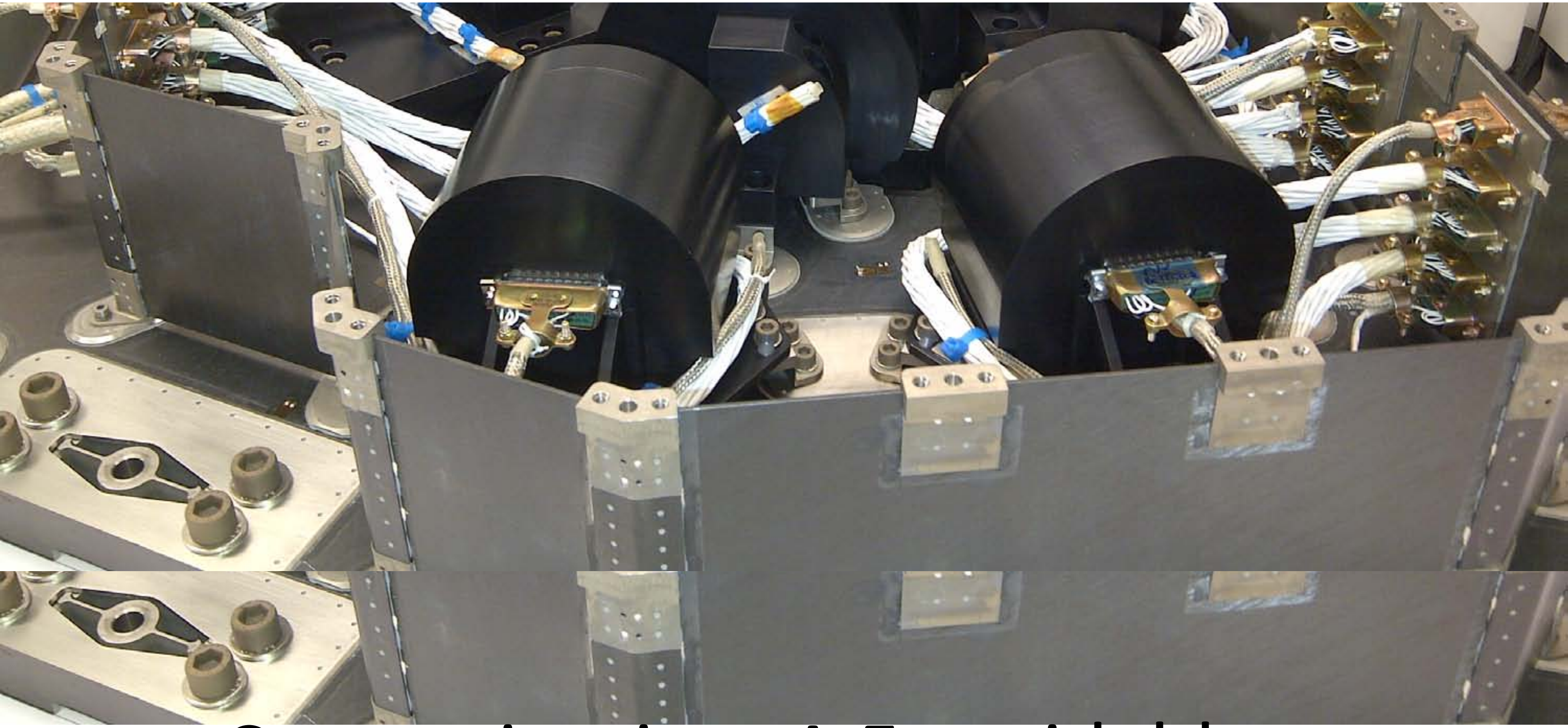
SENER Ingenieria y Sistemas



Contamination: A Formidable Challenge to Flight UV (FUV) Instruments

Thermal Stability Requirements for FUV

- **Ultralow thermal expansion coefficient (TEC)**

  - **Requirement drives design of optical bench (OB) to employ composites for OB structure**

  - **Low TEC very tight alignement for metallic inserts**
  - **Very critical for large FUV instruments (HST)**
  - **TEC within plane of OB is the most difficult to meet**

- **OB for small FUV OBs can be designed using conventional metallic materials (Al) and meet thermal stability through the use of heaters and flex elements (Galex)**

S/C and Instrument Contamination

- **Any event that results in performance degradation of critical S/C surfaces and instrument optical systems caused by the presence of particulate clouds and/or deposition of molecular and particles.**
- **Examples of critical surfaces are optical solar reflectors, mirrors, windows, optical sensors, etc.**
- **It is difficult to separate on-orbit contamination from aging effects due to space environment**

Example: Typical Requirements for UV Optical Bench

- **CTE (Coefficient of termal expansion) within plane: equal or lower than 0.2 ppm/C**
- **Inserts alignement: within 20 milliarcsec**
- **Flatness ratio< 0.05 mm/meter**
- **Lowest natural frequency: > 150 Hz**

Experience with WSO-UV ISSIS

Molecular contamination.

- **ISSIS molecular contamination level per optical surface shall be lower than 15Å [T,threshold], 10 Å [G, goal].**
- **Threshold requirement is equivalent to 10% radiometric degradation per surface at Ly-alpha.**
- **This requirement is roughly equivalent to 1.5E-7 g/cm2 [T], 1.0E-7 g/cm2 [G] at EOL.**

Particulate contamination.

- **ISSIS particulate contamination level shall be <3000ppm for RM and <1000ppm for other optical surfaces (i.e. MIL-STD-1246b cleanliness levels 500 and 400).**
- **This requirement is equivalent to a 5% radiometric degradation (total) in NUV channel.**
- **A higher contamination level was assigned to RM. Highly dependent on the S/C integration conditions, launch contamination, and on-orbit EOL budgets.**

Contamination Effects

- **Contamination causes diminished optical throughput, creates off-axis radiation (particle clouds), produces obscuration, and increases mirror scattering.**

- **Contamination control is vital in aerospace optical systems to maintain high reliability and clarity of images.**

- **Surfaces of UV components are very sensitive to contamination**
  - **Total mass loss**
  - **Moisture desorption**
  - **Collected volatile condensable material (CVCM)**

Deep outgassing

- FUV instruments require deep outgassing of non-metallic materials to assure that CVCM will not be released on-orbit and contaminate surfaces
- Deep outgassing changes the structural properties of the composite OB and assembly epoxies
  - OB TCM, strength, and natural frequencies will change after deep outgassing
  - These changes affect drastically the AIV sequences such as vibration tests, thermal stability, and optical calibration must be performed within a controlled environment, free of moisture and other contaminants

Partial List of Contamination Threats

- Ground, launch and on-orbit operations generate opportunities for the occurrence of contamination.
- Cleanliness levels requirements at the beginning and end of mission
- Contamination control
  - Self-contamination
    - Design configuration
    - Materials selection and conditioning (deep outgassing of H_2O and CVCM)
    - AIV processes and procedures
  - Cross contamination with other instruments
    - S/C Integration with flight instruments
  - Launch preparation and ascent phase
    - UV instrument protection (purging?)
    - Venting strategy
  - On-orbit operations
    - Residual outgassing of H_2O and CVCM from non-metallic materials
    - Thruster operations
    - S/C environment: molecular, particulate, electrons/ions, high energy particles

Sources of Contamination 1

- The major sources of **molecular** contamination are:
  - Manufacturing residues (machine and cutting oils) which result from fabrication of hardware.
  - Material outgassing.
  - Space vehicle surface outgassing during ascent, deployment, and orbital operations.
  - Ground and air transportation environments.
  - Volatile condensable materials in the environment to which contamination-sensitive, critical surfaces may be exposed during assembly operations.
  - Return flux of outgassed molecules due to collisions with residual atmospheric molecules.
  - Propulsion system plume impingements causing deposition of nonvolatile substances on optical surfaces.

Sources of Contamination 2

- The major sources of **particulate** contamination are:
  - Airborne particulates settling on hardware surfaces during manufacturing, assembling, and testing operations.
  - Paint overspray, insulation shreds, clothing fibers, and other human-induced substances.
  - Trapped particles on internal surfaces of subassemblies and in other hardware crevices. These are released and redispersed from acoustic vibration, transportation, and launch.
  - Reaction control system (RCS) or main propulsion system plume exhaust and flash evaporator water release that may create residual cloud environments

Contamination Control Plan

- Controlling contaminant production and transport minimizes system performance degradation caused by
  - The deposition of molecular contaminants on mirrors, optical sensors and critical surfaces
  - Improves cost-effectiveness of mission results; and improves reliability

- Contamination control of space optical systems consists of the planning, organization, and implementation of all activities needed to determine, achieve, and maintain the required cleanliness level of the optical system all the way, from fabrication to the end of the mission.
- Each optical system has its own unique contamination control requirements.
- The most affected are the AIV procedures

On-orbit Consequences and Cautions

- Residual particles from AIV and launch are detached and redeposited on exposed surfaces
- NH3 from hydrazine propulsion systems and CVCM can polymerize on optical surfaces when exposed to the UV
- Heaters should be installed near optical surfaces to sublimate condensables and other materials accumulated on those surfaces when on orbit

Conclusions

- **Contamination control is vital in aerospace optical systems to maintain high reliability and clarity of images, PARTICULARLY IN UV FLIGHT INSTRUMENTS**
- **Ground, launch, and on-orbit contamination prevention, detection, and control are essential for high-resolution space optical systems (and also for balloon based measurements).**
- **At system engineering level, coordination of contamination control engineering is crucial for a successful design, development, integration, verification, delivery into orbit, and as far as the end of mission.**
- **In-depth studies have shown that contamination avoidance is feasible and enhances mission success**
- **The challenge is aggravated when UV flight instrument is integrated with spacecraft, large telescopes, and other flight instruments**
- **If the material properties change with deep outgassing, a series of painstaking and expansive set of procedures needs to be undertaken to assure that ground tests for mechanical verification and calibration are representative of flight conditions, while simultaneously keeping the sensitive surfaces at the design level all the way to the end of life.**