Overview of Material Challenges for Earth Observation missions.

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Potential Issues (1)

- **Stability**
  - CTE effects of adhesives, coatings
  - Delamination of coatings, composites

- **Contamination**
  - Coatings with low or no organic content
  - non-friable coatings (generation of particulates)
  - Low outgassing silicones

- **Storage**
  - Use of multi-satellite observation platforms ➔ long manufacturing time scales and hence long on-ground storage times

- **Qualification Limits**
  - As extreme temperatures approached can mean that the qualification limits are outside acceptable materials limits even if the operational range is within tolerance; for Earth Observation satellites (low orbits) typically the number of cycles is very high and often more critical than the actual range
Potential Issues (2)

- Temperature ranges
  - Cryogenic conditions
    - Temperatures now exceeding -100°C ranges. Results in most organic materials going through a glass transition temperature → changes in behaviour and stress state. Also causes problems for materials testing and validation.
    - Examples include delamination of composite panels, loss of peel strength in adhesive tapes, development of misalignments through CTE issues
  - Operational lifetimes
    - Lifetime requirement (up to 10 years) can become very demanding when it is combined with the high number of thermal cycles; fatigue failures and thermal cycling cracks can be quite common
  - Extreme temperatures
    - Temperatures above glass transition can of course be detrimental for structural applications; in addition to that, material properties are normally tested at ambient conditions
• Optical Coating
  – Improvements in AR coatings
  – Verification of survivability at extreme temperatures

• Adhesives/Encapsulants
  – Improvements in adhesive strength
  – Wider operating temperatures
  – Verification under extreme environments
  – Stewardship and continuity issues associated with changing legislation and economics, together with changing military restrictions (ITAR)

• Composites
  – Improvements in stiffness and strength
  – Wider operating temperatures
  – Verification under extreme environments
  – Stewardship and continuity issues associated with changing legislation and economics, together with changing military restrictions (ITAR)
Potential Issues (4)

• Paints & Coatings
  – Improvement of absorption/emissivity
  – Development of inorganic coatings
  – non-friable
  – Wider operating temperatures
  – Verification under extreme environments
  – Stewardship and continuity issues associated with changing legislation and economics, together with changing military restrictions (ITAR)
Examples

- Cryogenic failure
  - Pull-off of harness staking from composite surface
  - Due to operation below Tg
  - Failure was not in adhesive strength of rubber
  - Failure occurred in composite surface due to localised stresses generated
Examples

- Cryogenic Failure
  - Delamination of Composite Panel coating
  - Associated with extreme temperatures and presence of inserts ➔ CTE effects
Examples

- **Cryogenic failure**
  - Loss of peel adhesion in acrylic adhesive tapes
  - Static adhesion in shear on rigid substrates retained
  - Due to glass transition temperature at -50°C

![Graph showing Lapshear Strength vs. Temperature](image)

90°Peel strength

![Graph showing Peel strength vs. Temperature](image)

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Examples

- Thermal cycling
  - Delamination
  - Due to asymmetrical CTE effects during thermal cycling
  - Stress state induced a high peel stress at adhesive interface
  - Stresses caused a “banana” like flexing of the panel

Delamination
Examples

- Loss of Seal performance during qualification tests
  - Rubber operating near glass transition
  - Frequency of operation resulted in effective Tg being reduced
  - Failure occurred during qualification because of addition of qual. Margins

DMA Measurements on Rubber
• Failure during qualification testing
  – Ceramic transistor LCC3
  – Solder joints after vibration and thermal cycling.
  – View of the micro-section through the solder joint
  – showing a crack extending from the heel to the toe fillet.
Example

- Failure during vibration testing
- FPGA lead
- Failure by fatigue
- Presence of fatigue striations under high magnification SEM
• The Mission objective is to reach a very accurate measurement of the Earth gravity field and gradient

• The orbit is very low ~ 260 Km

• A carbon – carbon structure was utilized for 3 panels used for mounting of the accelerometers in order to have a very high dimensional stability → this technology was new and it was developed specifically for this application

• The Solar Array panels that are very elongated presented many delamination defects → there was a transfer of technology from a company to another
• Atomic Oxygen resistant materials were carefully selected for exposure to flight direction because of the very low orbit.
• A ceramic glue (high temperature resistant) used on the thrusters presented an application problem with presence of many cracks.
GOCE in Plesetzk

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SENTINEL2

- The orbit is sun synchronous at ~ 800 Km

- Cleanliness requirements for MSI payload (IR instrument) are very stringent

- An Aktar Black coating was used for the IR detectors and this material has very high RML and CVCM → a specific test was organized in Estec laboratories to demonstrate that for in-orbit conditions there was no permanent ice forming
Overview of MSI instrument
SENTINEL3

- Multi purpose mission for ocean and land colour, ocean and land surface temperature and surface topography
- The orbit is almost polar, sun-synchronous at about 815 Km
- The main challenge is to guarantee the required cleanliness levels for the 2 very cold detectors (one in visible and one in infra-red)
- Bake-out of many outgassing items is foreseen and cold-traps to collect residual contaminants will be also implemented
Sentinel 3 overview
• The mission objective is to measure the thickness evolution of the main sea and land ice fields by means of a high resolution altimeter.

• The orbit is a near circular polar orbit (not sun synchronous) at ~ 717 Km altitude and with an inclination of 92 degree.

• CS2 has big SA panels body mounted (see following photos) with a size of 3 x 1.1 m and the main challenge was to guarantee the required flatness to the CRFP panels.

• Very stringent dimensional stability requirements are applicable to the two radar antennas because they work on phase difference (see following photos).
CRYOSAT2
CRYOSAT 2
• The mission objective is to measure the wind speeds at different altitudes (from sea level to 20 Km) by means of a laser doppler instrument working at 355 nm (Aladin)

• The orbit is a sun synchronous low orbit at 408 Km altitude, with an inclination of 97 degrees and a repetition period of 7 days (every 109 orbits)

• Due to the lack of a technological heritage the laser development had to face (and it is still facing) many unexpected and also expected issues
A view of Aladin telescope with the laser radiator
ADM Aeolus

A view of Aeolus platform during AIT tests in Stevenage
• Laser Induced Contamination (LIC) is well known for a UV laser; basically even very small traces of organic materials can form deposits of contaminants on optics under the action of the UV laser beam (with a reduction of optical performances)

• The Laser Induced Damage (LID) can be a consequence of LIC since the presence of contamination deposits on optics can lead to overheating of optical coatings

• To avoid LIC, Aeolus items were submitted to extensive use of bake-out in vacuum (e.g. Solar Arrays, MLI, tye raps, telescope, antennas….); in addition to that, silicon based materials were banned because of their strong contamination effect
• Some optical coatings had to be replaced because they showed a shift of their spectral response during transition from air to vacuum

• A polyurethane glue used for mounting of optical parts was replaced by epoxy because it was unstable during transition to vacuum because of water release

• Betacloth with graphite had to be replaced with the normal Betacloth because it showed very bad behaviour w.r.t. Atomic Oxygen erosion
ADM Aeolus

- Thermal conductance of indium filler material is affected by the transition from air to vacuum and this caused a change of performance of laser pump units with instability of laser beam pointing (see fig. below showing evolution of deltaT)

- Many tests for characterization of LIC behaviour of materials have been carried out in Estec laser labs whereas the indium filler test was performed in Estec materials lab. This shows the importance of having advanced laboratories readily available to close technical discussions in a short time
Earthcare

- The mission objective is to explore Earth clouds and aerosols

- Atlid payload, that is also a UV laser, could have problems very similar to Aeolus (LIC and instability in air to vacuum transition) and because of that it has been decided to make it pressurized