Engineering, Operations & Technology
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The Komplast Experiment: Space Environmental Effects after 12 Years in LEO (and Counting)

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The Komplast Experiment

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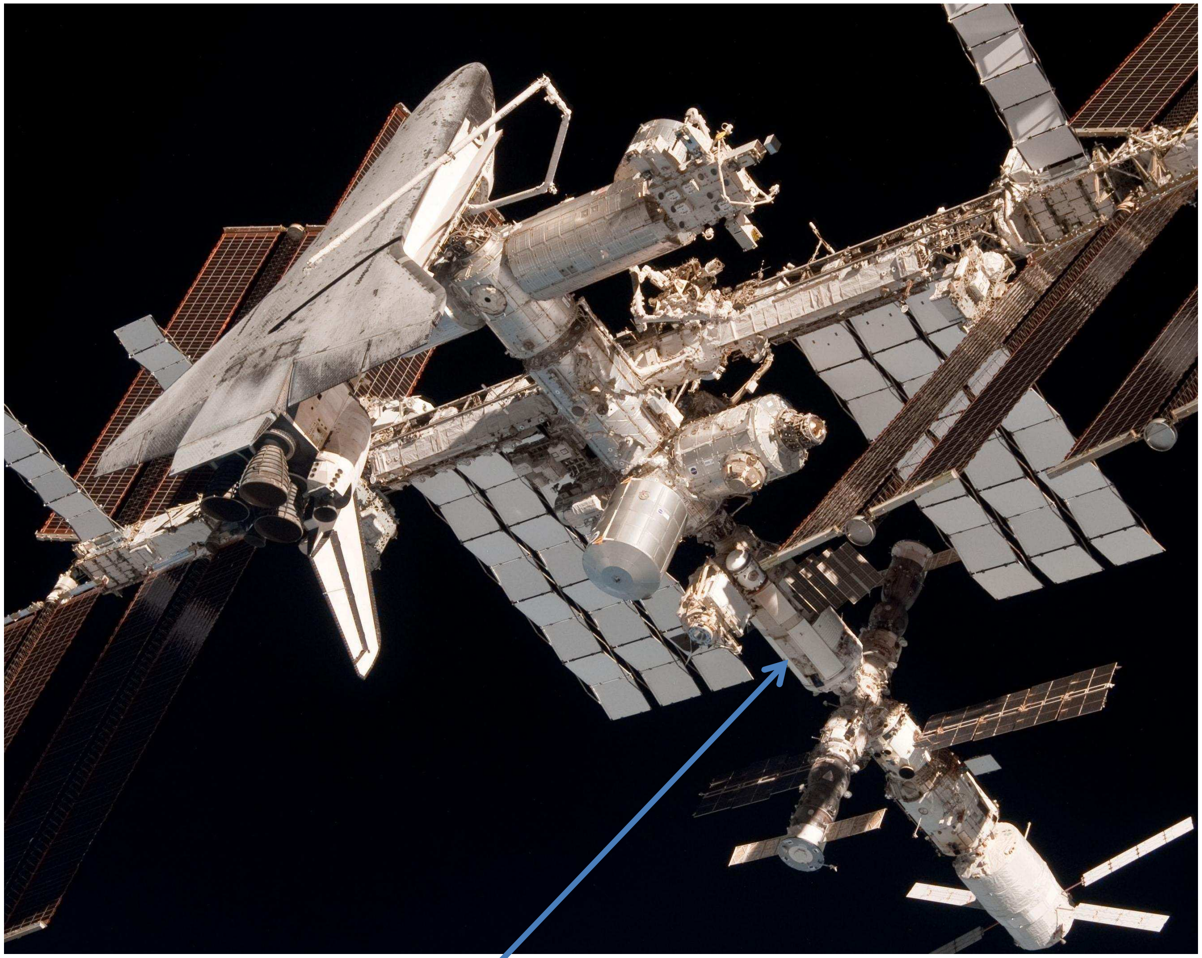
The Komplast Retrieval Purpose

- **The FGB module, like most of the ISS Vehicle was originally designed for a 15 year operating life.**
  - **Launched in late 1998.**
- **ISS Service Life Extension efforts seek to determine if the ISS Vehicle can be reasonably maintained in operation through 2028.**
- **Komplast panels were selected to obtain materials specimens which would best support the service life extension objectives.**
  - **Assessing risk of continued operation beyond original design life.**

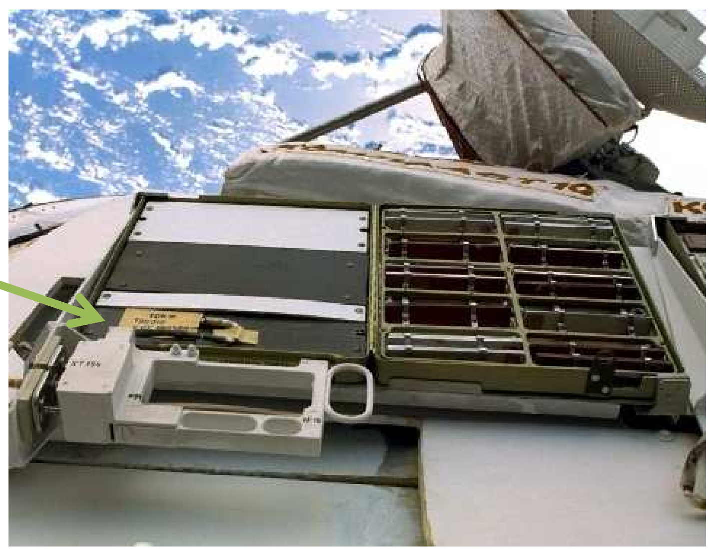


FGB – “Zarya”

Background - The Komplast Experiment

- Komplast is a space environmental effects experiment, exposing samples of spacecraft materials of construction to space and providing some determination of the nature of the International Space Station (ISS) space environment (sensors).
  - Similar to the Materials ISS Experiment (MISSE) conducted by US researchers and the SKK experiments conducted by RSC-E.
  - Most samples are passive, but there is some telemetry (temperature example below).
  - Materials: Elastomers, plastics, thermal control coatings, composites, adhesively bonded specimens, fabrics, cable harness materials, composites, sealants, and films.
- The unique aspect of Komplast is the very long exposure time.
  - **12 years and 2 months exposure to space, for the work reported here.**

Temperature Sensor

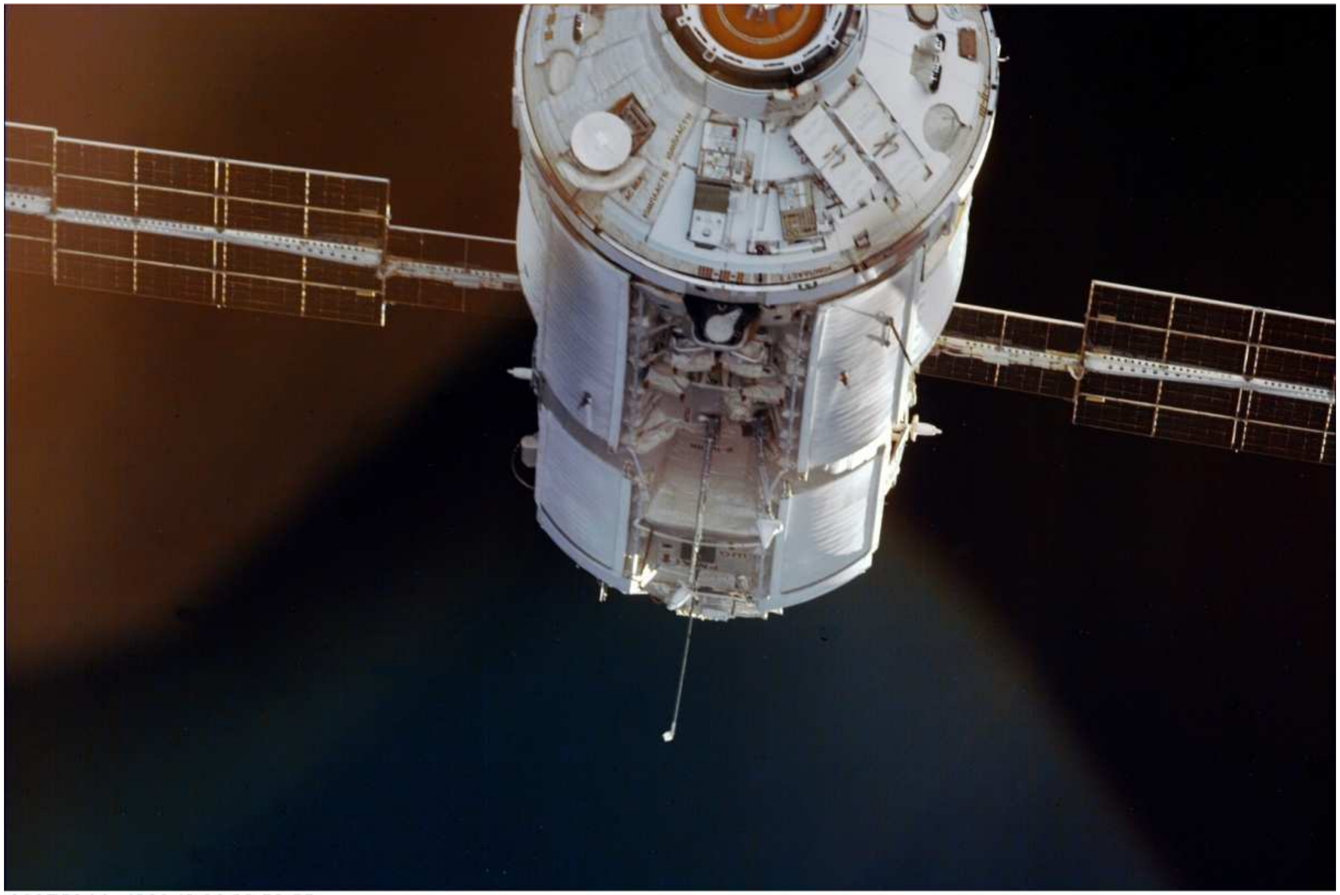


Komplast Panel #10, on-orbit

Komplast Panel #2, on-orbit

Background - The Komplast Experiment

Komplast panels were integrated onto the FGB module (the first ISS flight element) and open (except Panel #3 and #10) at launch. Panel #10 was opened during EVA3 on ISS Flight 2A (covered ~3 weeks).



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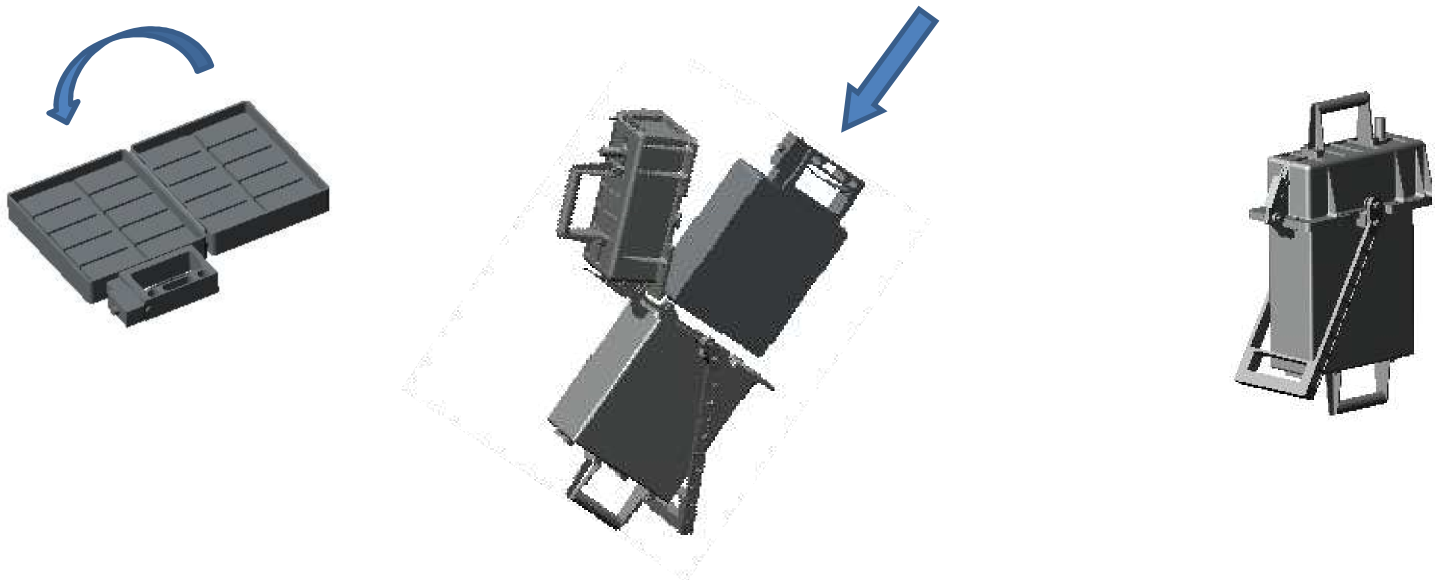
Background - The Komplast Experiment

- **The deployed Komplast Panel is closed during EVA retrieval to protect the exposed samples (like a suitcase).**
- **Two closed panels fit into a Komplast transportation canister.**
- **The closed canister includes a sealing interface to inhibit the ingress of atmosphere.**



Background - The Komplast Experiment

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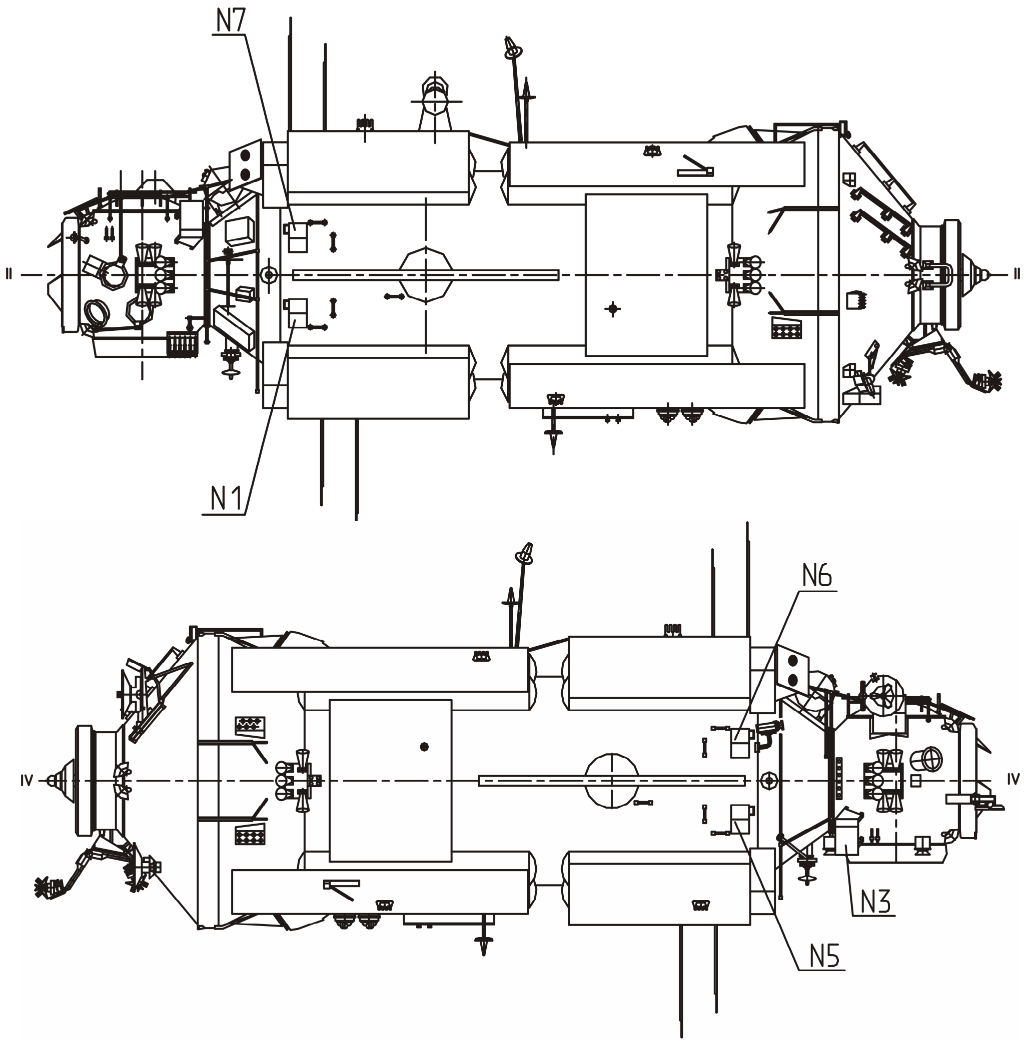
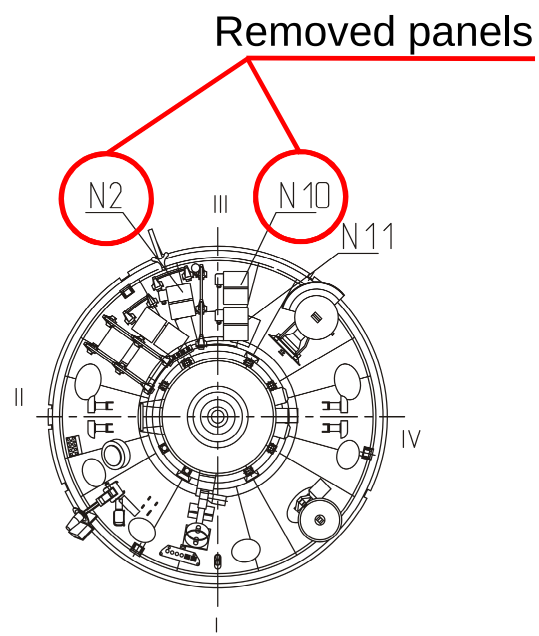




There were eight Komplast panels on the FGB

The Komplast Environment

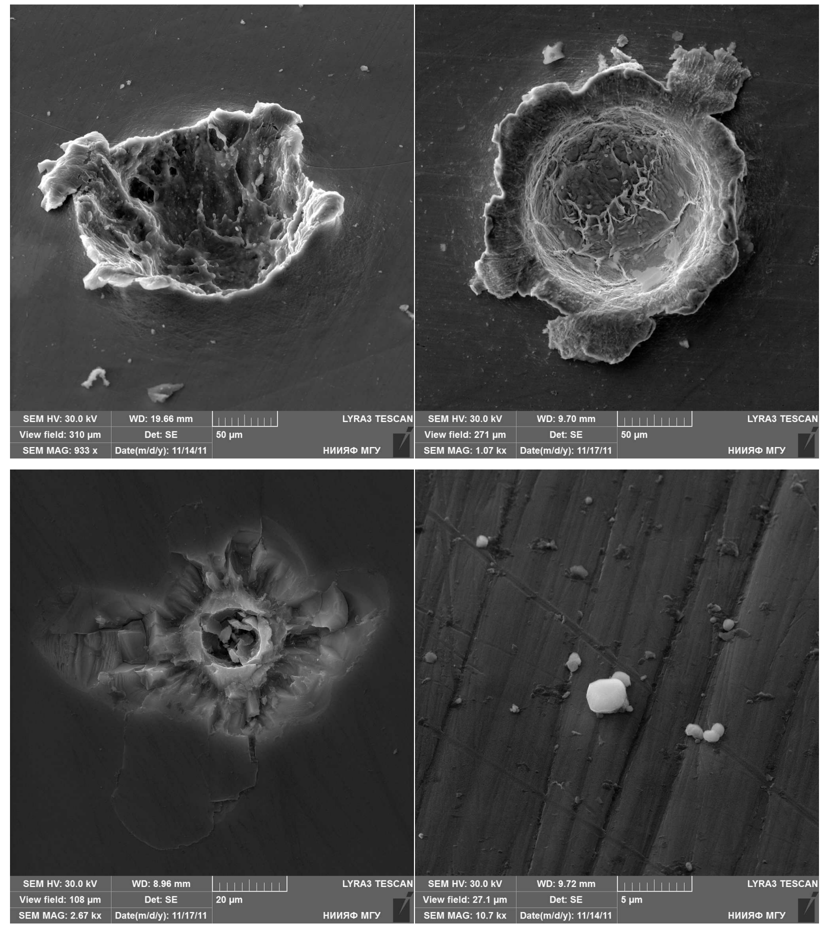
- **The Komplast transportation canister was analyzed for gas content prior to actual opening to remove the two panels.**
  - **Pressure ~0.5 atm and ~6% Argon, indicating loss of seal integrity.**
    - **Argon was from packaging for shipping: KSC to Moscow.**
- **Thermo-optical properties of TP-CO-2 radiator coating were measured under vacuum conditions and found to correspond with degradation expectations.**
- **Temperature telemetry measured ranges of +85°C to –80°C for Panel #2, and +107°C to –80°C for Panel #10, with 20±10°C average for both panels.**
- **Solar ultra-violet (UV) radiation on each panel was determined from the temperature telemetry (cumulative solar illumination time).**
  - **Estimated at 957±200 kJ/cm^2 or 21,000 ESH.**
  - **For the Mir space station, UVR for 15 years amounted to 1500 kJ/cm^2 or 33,000 ESH.**
- **The ionizing radiation sensor on Panel 2 was saturated (designed for 5 yrs.).**
- **Atomic oxygen fluence was determined from specimens with know erosion rates from previous SEE experiments.**
  - **Estimated at 1.5x10^{21} O atoms/cm^2.**

The Komplast Environment

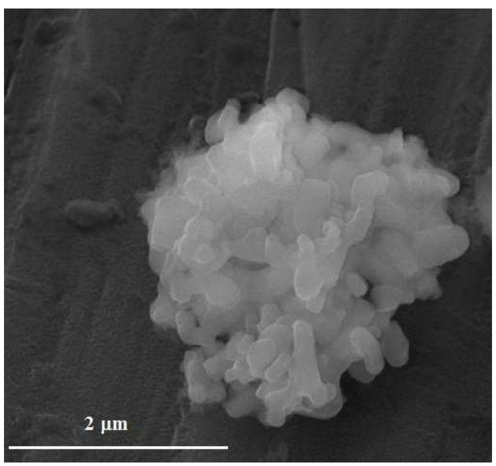
Micrometeoroids and Orbital Debris (MMOD)

1. Micrometeorites classification into natural and artificial (chemical and physical characterization).
2. Determined the character of interaction between micrometeorite particles and different types of materials.

Al Cu



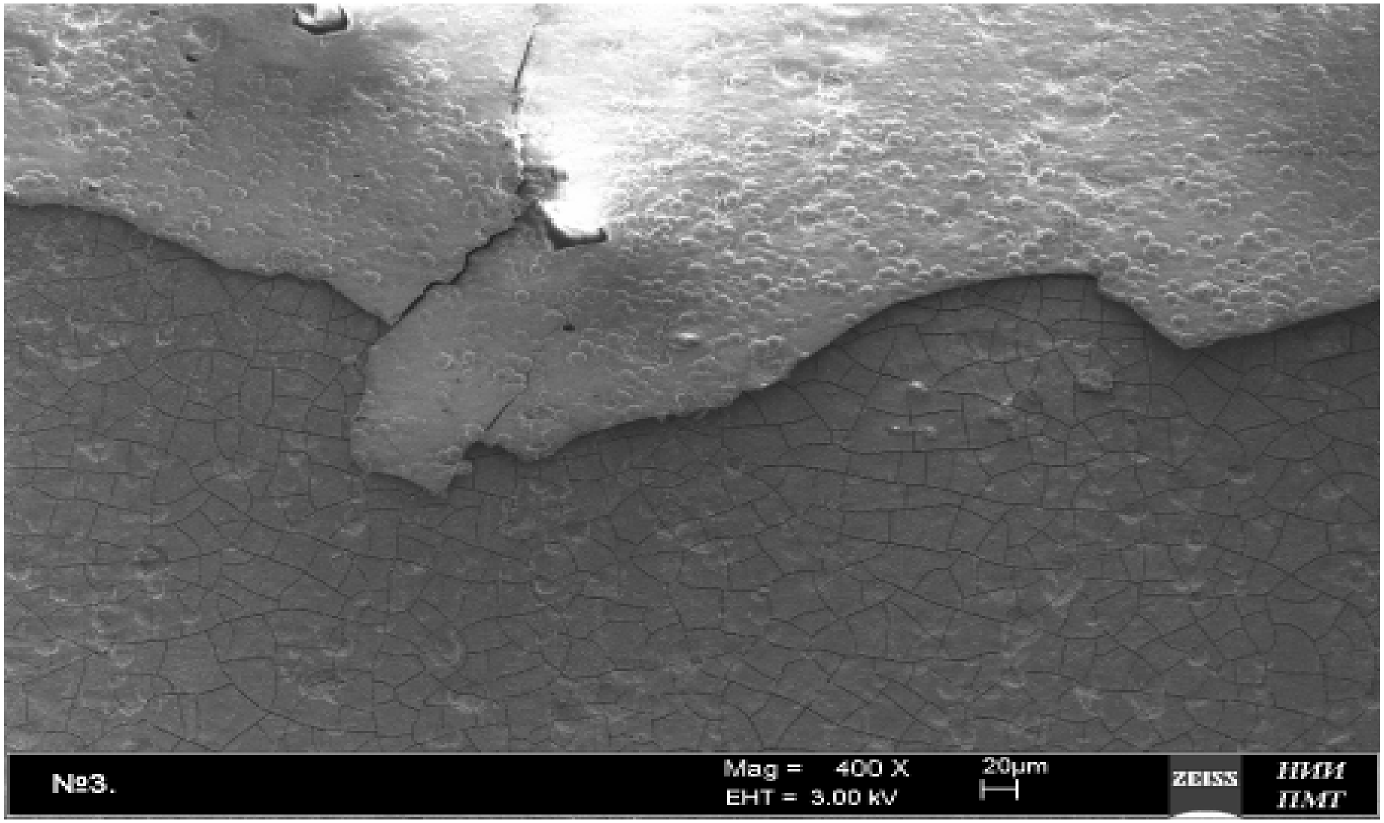
Si Ti



Particle imbedded in Ti

The Komplast Environment

- Surface contamination was assessed.
  - Most heavily localized around the rubber samples, primarily consisting of silicon oxide (oxidized silicone plasticizers).

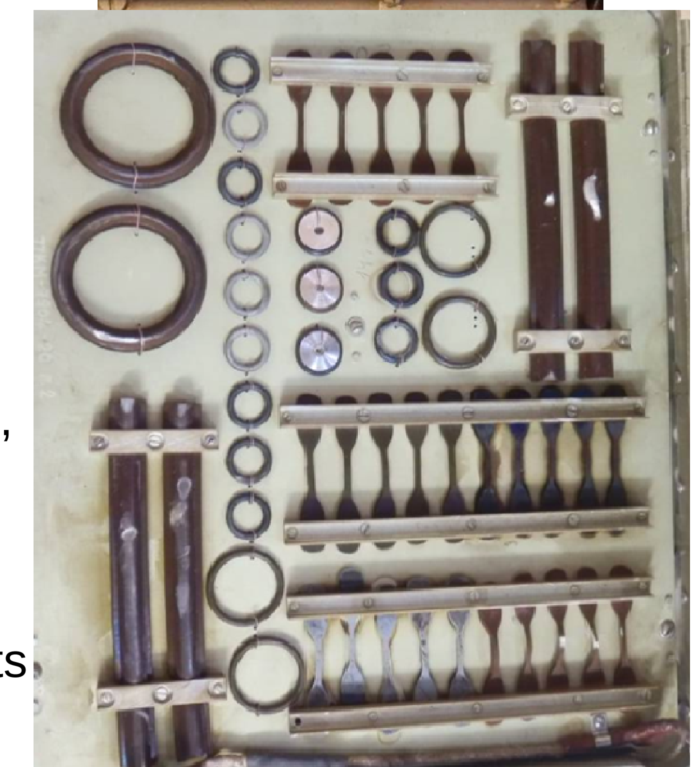


Contamination film (top) on the Komplast Panel surface.

Komplast Results – Elastomeric Materials

- Seal Materials on Panel No. 2 consist of the following:
  - ИРП-1118, methyl styrene rubber-based
  - ИРП-1175, nitrile rubber-based
  - ИРП-1399c, vinyl silicone rubber-based
  - 51-1447, methyl styrene rubber-based
  - 51-1567, fluorosilicone rubber-based
  - 51-2066, fluorosilicone rubber-based

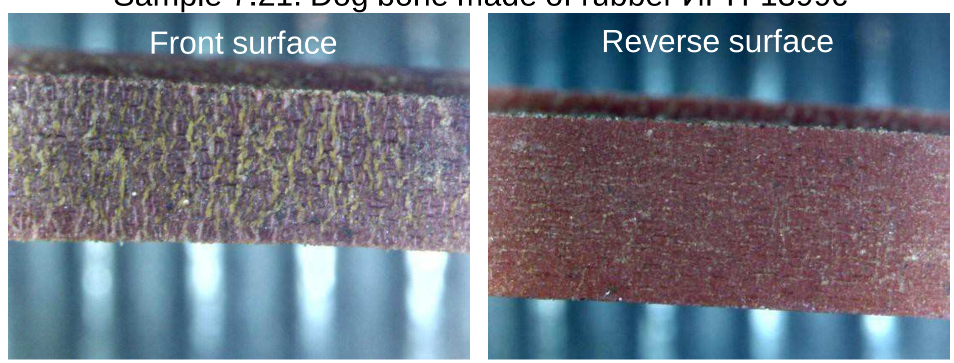
- Detailed visual inspections of all samples (macro and micro examination)
- Material properties testing after space exposure (hardness, sealability, leakage, frictional coefficient, elongation, residual strain, etc.)
- Additional atomic oxygen (AO) and radiation on select samples were performed to demonstrate 30 year life with thermal aging residual strain effects



Komplast Results – Elastomeric Materials

- **Exposed specimens all demonstrated preservation of their volumetric strain and relaxation characteristics.**
- **All rubber types exhibited disintegration and partial separation of the exposed front surface layer during up to 50-per cent extension, but without bulk volume damage.**
- **This long-term exposure to UV and AO and consequent surface modification resulted in a seal performance mechanism change from a diffusion leak path to a contact leak path.**
- **Areas protected/screened from long-term UV and AO (but still exposed to ionizing radiation and thermal vacuum cycling) still maintained their as- designed sealing properties.**

Sample 7.21. Dog bone made of rubber ИРП-1399c



Expansion 50%

Komplast Results – Adhesive Bonded Materials

- **The adhesive specimens research carried out made it clear that all types of adhesive-bonded joints remained serviceable as components of FGB module construction for 30 years from the date of beginning their service under space conditions.**
- **Samples were of Aluminum (Д-16) or fiberglass laminates (КАСТ-В) substrates with epoxy adhesives К-300, ЭПК-1 or ВК-9**
- **Some specimens were post irradiated and thermal aged to provide predictions for 30 year life**
- **Extensive visual and material property data obtained**

Specimen No. 24,
КАСТ+ ВК-9 + КАСТ constituents

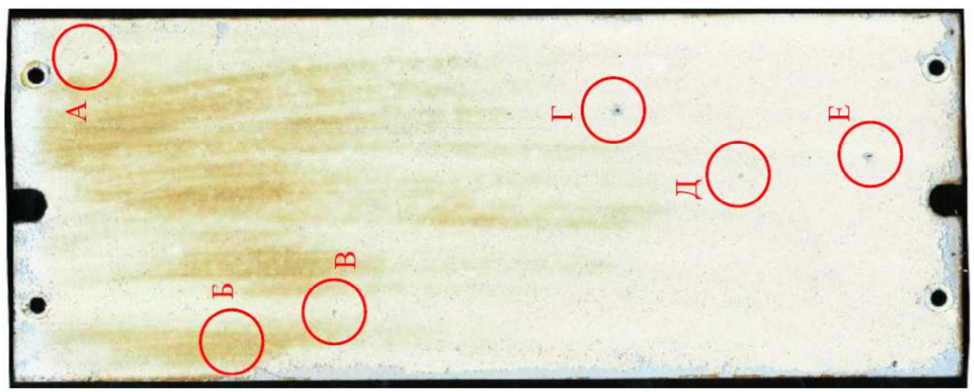
- The failure mode of all adhesive-bond joints analyzed occurred adhesively, i.e. along the adherent boundary, while the polymer base of all adhesive coats (cured epoxy polymer) is space factors-resistant. Essentially, in adhesive-bond joints the adhesive is well protected by the adherents from the direct effects of space environment factors.

Komplast Results – Cable Materials

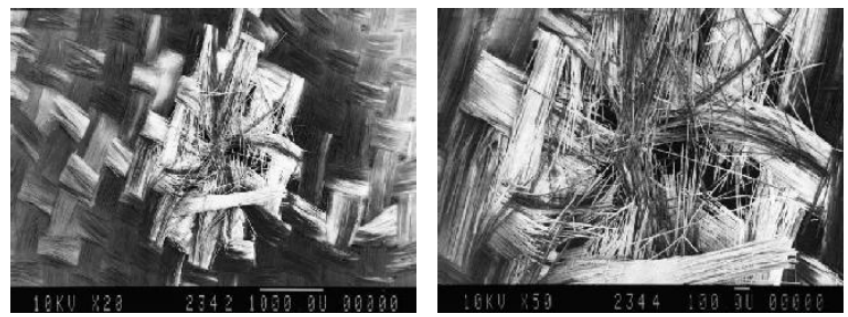
- **Cabling materials on Panel No. 2 were evaluated, including wire bend testing post-exposure.**
  - **Durability results varied by material, but results were typically good, especially when compared to the much more benign environment to which these materials are exposed on the FGB vehicle itself.**

Komplast Results – Carbon Composites

- **Composite polymer КМУ-4лс was evaluated, some of which was bonded to aluminum alloy sheets of АМг6 using epoxy adhesive ВК-9, and some as samples coated with white thermal control coating ТР-СО-2.**
- **Some small MMOD damage was observed and evaluated using detailed visual inspection (including microstructural using Scanning Electron Microscopy) and chemical analysis.**
- **Three point bending tests indicated no critical changes from exposure.**
- **A protective outer layer in the composite lay-up completely prevented significant microstructural changes in the composite.**



Carbon composite КМУ-4лс with white thermal control coating ТР-СО-2, showing several MMOD impacts.



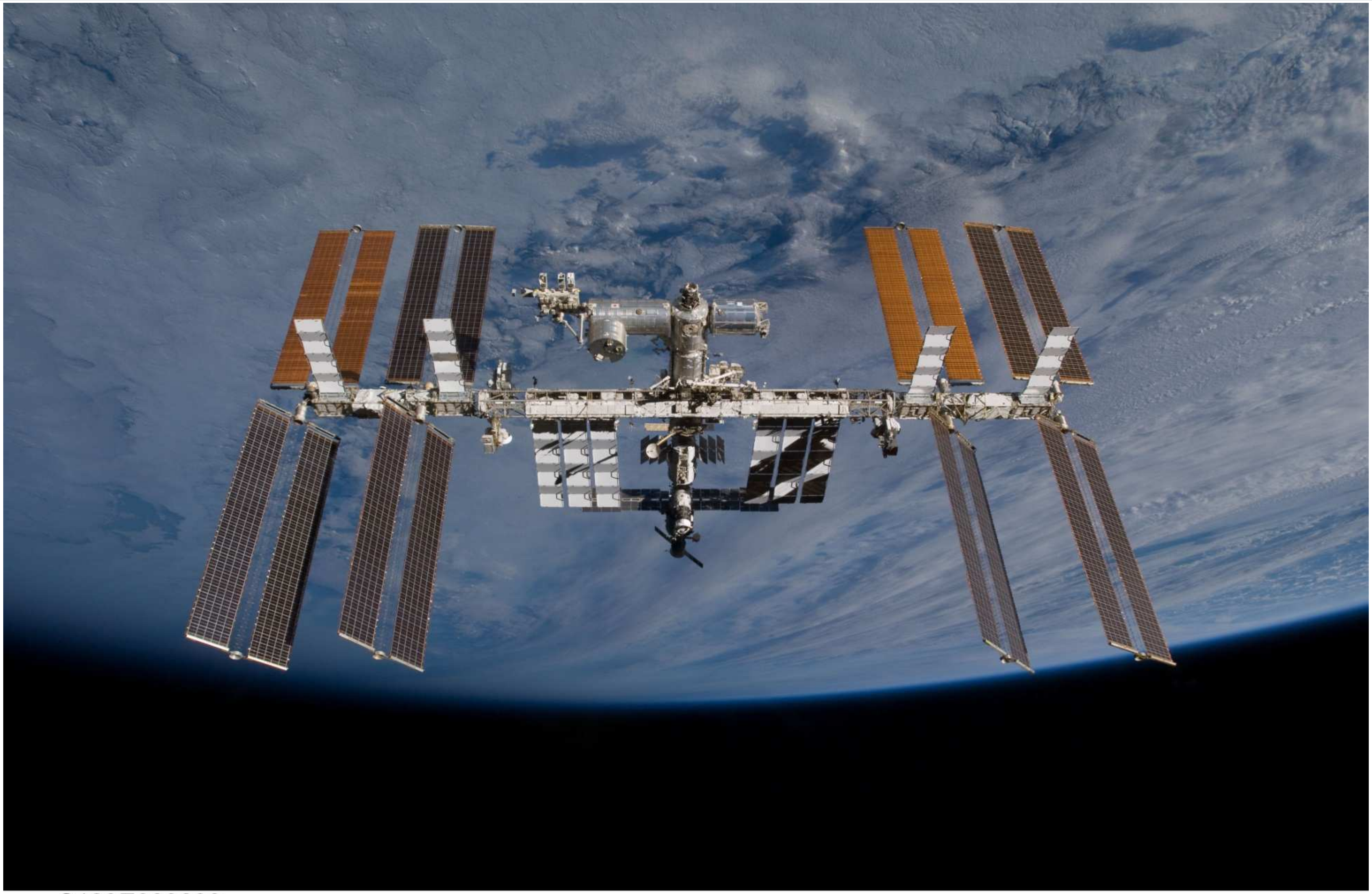
Carbon composite КМУ-4лс without thermal control coating, showing MMOD impact close-up.

The Komplast Experiment

CONCLUSIONS

- **The analysis of retrieved Komplast panels improved our understanding of the changes taking place in specific, priority FGB materials of construction and made it possible to confirm no less than 30 years of service for those FGB module materials from space environmental effects and general aging perspectives.**

The International Space Station



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