Rendezvous Sensor on ATV:

Fiber Optic Link of Optical Head and E-Box

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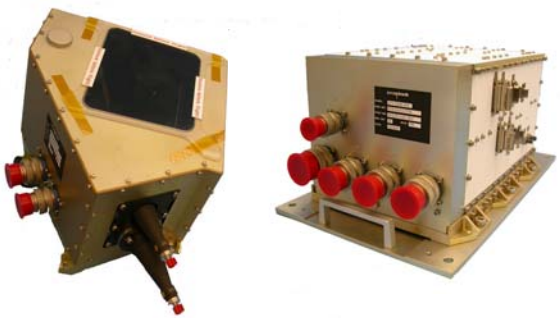

Sensor Heritage and Application

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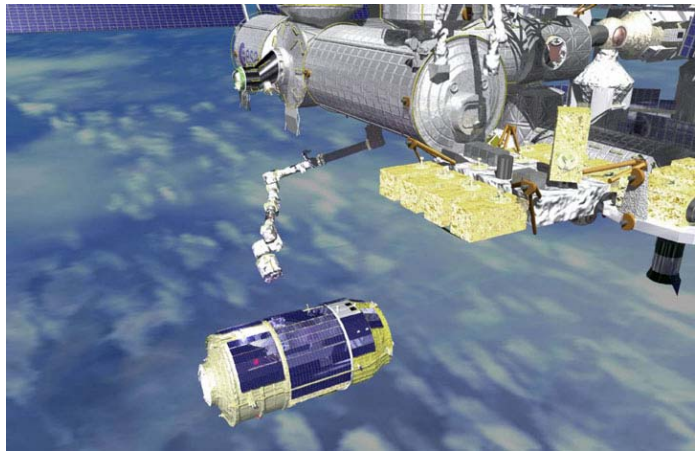
STS - 84 Mai 1997

STS - 86 Sept. 1997

Successful Space Application of Precursor Model ARP-RVS on Shuttle Atlantis during MIR Missions



RVS is the only rendezvous sensor for berthing of the Japanese HTV

RVS is one of the docking sensors on the European ATV

Sensor Principle

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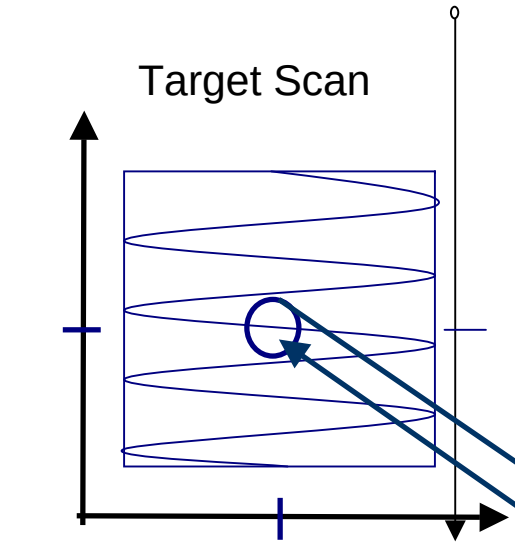

Fibers are applied inside the LRF and between LRF and Optical Head

E-Box

-Laser Range Finder
-Scanner Electronics
-Micro Processor
-Interface
-Power

View into the Optical Head

Optical Fibers on ARP-RVS

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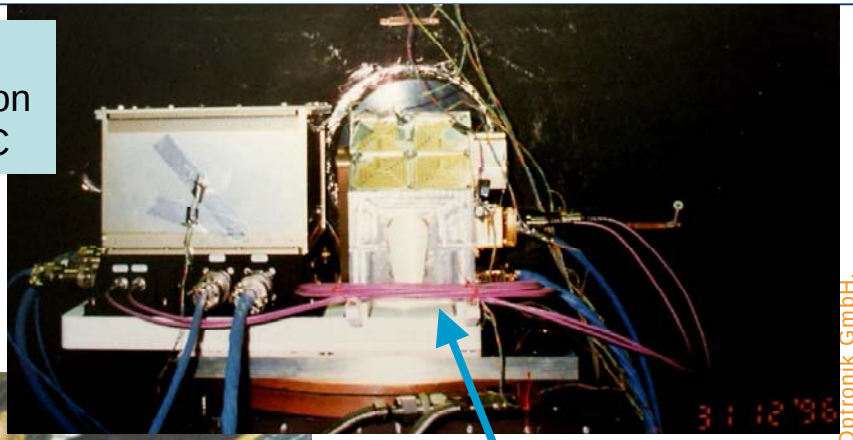
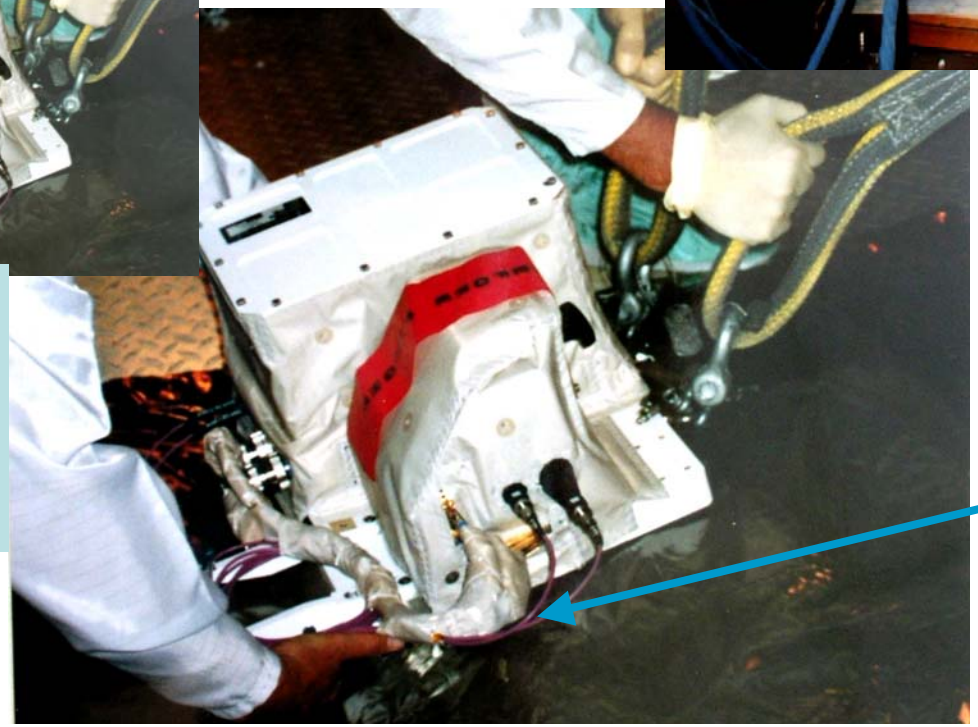
ARP-RVS qualification in the TVC



ARP-RVS dismounting after Shuttle Mission STS-84



Optical Fiber (Manufacturer: 3M)

Optical Fibers on ATV/HTV-RVS

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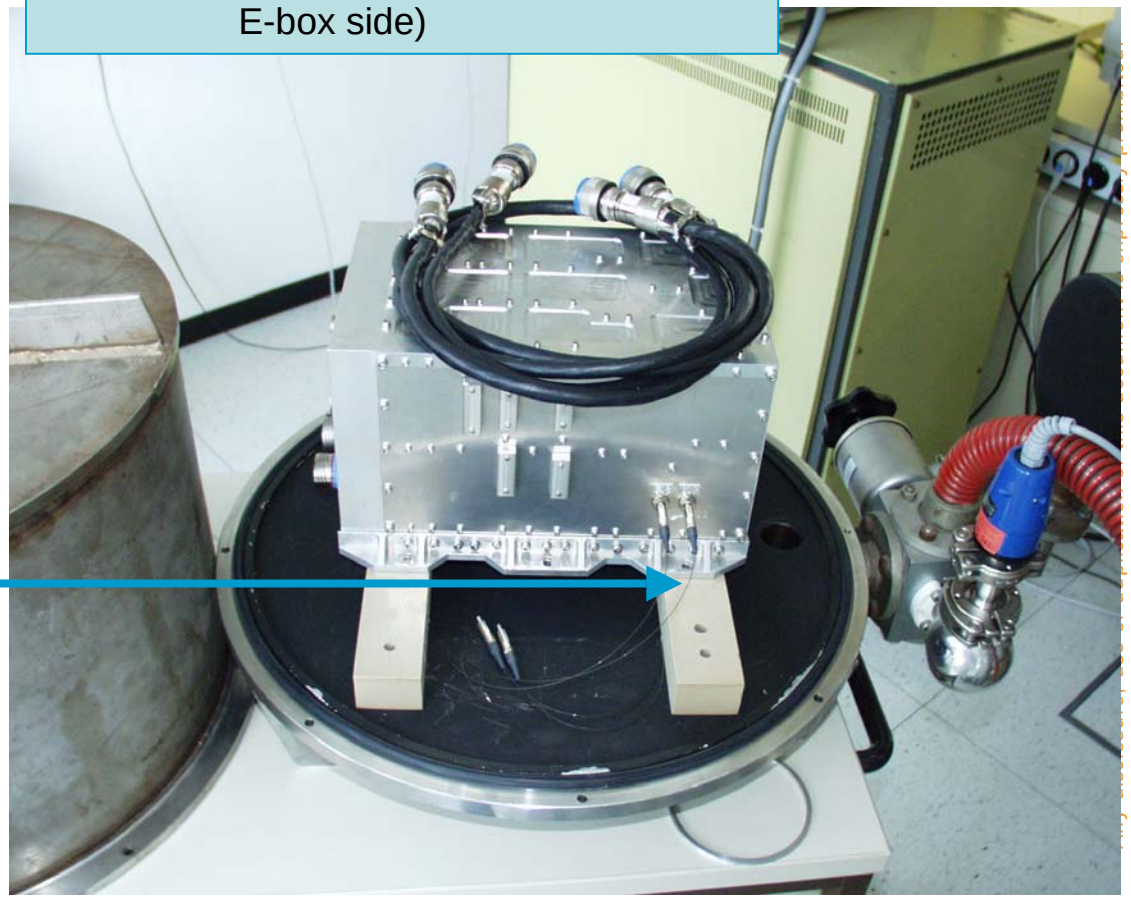
Photo: RVS-EQM during preparation of the Depressurization test.

(The fibers are are plugged on E-box side)



ATV/HTV RVS Fiber cables:

Fiber manufacturer:
FiberTech Berlin

Preform manufacturer:
FiberCore Jena
(now: j-fiber)

Cable assembly:
Astrium Ottobrunn

Transition from ARP-RVS Fiber to the ATV/HTV Fibers

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Core ∅ of all fibers: 200µm; ∅ incl. cladding: ≈ 280µm

ARP-RVS	ATV/HTV-RVS
Fiber application for Connection LRF - E-box-IF Connection E-box - Optical Head incl. Mode-mixing	Fiber application for Mode-mixing inside LRF Connections LRF - E-box-IF - Optical Head
Fiber Type: Step index fiber for all applications	Fiber Type: Gradient index fiber inside E-box Step index fiber for connection E-box-IF - Optical Head
Poor traceability of fiber and cable manufacturing processes Some confusion in documentation, Degradation of the outer coating during and after integration and test processes (color, stiffness) ⇒ Decision to change the fiber cable provider for the next projects	Good traceability of materials and processes, In the mean time: good experience with the optical and mechanical properties of the fiber cables Only Exception: 1 fiber rupture during assembly on the ATV cone ⇒ investigated in detail

Investigations
after Fiber Rupture on ATV Cone

Situation:
Rupture on 1 fiber (step index) occurred abruptly during re-mounting of the fibers on ATV after 4 RVS models had been manufactured and extensively tested without any fiber problem

Measures to identify reason for the rupture:
performed together with specialists of ESTEC and of fiber manufacturing companies

- Detailed investigation of the previous ”life”of the ruptured fiber
- Detailed investigation of manufacturing processes and fiber properties
- Search in publications for potential reasons and similar effects
- Additional Proof-test on remaining fiber of the same charge
- Interviewing of persons who had handled this type of fiber
- Compilation of all acceptance and qualification documentation of the fiber

Results 1

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General Result:

The “one and ultimate reason” for the occurred single fiber break was not detected,

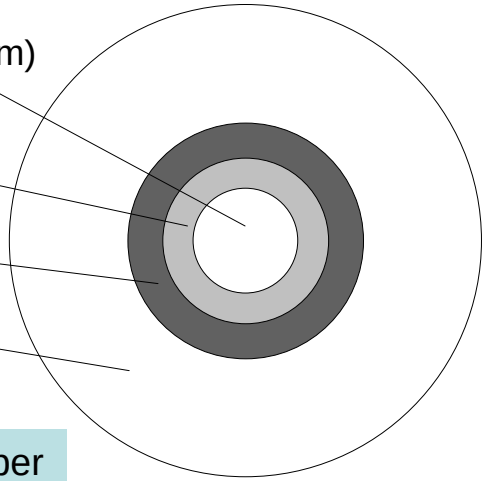
but a number of potential contributors to the rupture were identified, and several measures were fixed to minimize the risk for further break.

Undoped fused suprasil silica core -F100 (∅: 200µm)

Florine doped cladding (∅: 278µm)

Polyimide coating (∅: 310µm)

FEP secundary coating (∅: 600µm)



Cross section of the Step index fiber

Results 2

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A) Except the one fiber break during integration on the ATV cone, no further break occurred on the cables, neither during fiber cable assembly nor during handling in the RVS integration, qualification and test phases.

B) In general, short time bending of the fiber, even with an extremely small bending radius (e.g. wrapping around a pen) does not lead to fiber break.

C) Investigations by magnifying lenses and microscopes on the coating of fibers of the same charge did not identify indications for further break.

D) Intentionally applied cuts on the fiber coating increase the risk of break during subsequent bending.

E) The small outer diameter of the fiber leads to the effect that it may be overlooked after integration on ATV. So a risk of damage by uncareful handling during further integration steps exists.

F) Some irregularities were visible on the coating surface, not leading to increased risk of break

Surface irregularity on a cut of the Step Index fiber

Results 3

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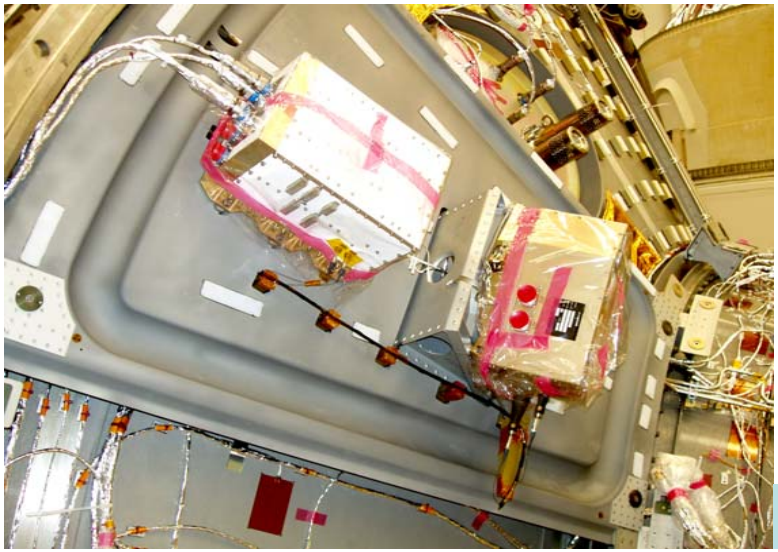
G)



RVS on the ATV cone

Appropriate fiber handling is an important prevention of fiber break. The broken fiber (as well as the 3 other fibers on ATV cone) were already fixed - removed - fixed resulting from incomplete integration of components around RVS. Pre-damage of the fiber coating by the applied tools (knife to remove tape) cannot be excluded.

H) Care must be taken on the bending radius of the fiber. The applied fixation by winding the fiber around a cable seams to be not optimum. An under-run of the allowable short term bending radius just before break seams probable.

Fiber winding around the Triax cable

Results 4

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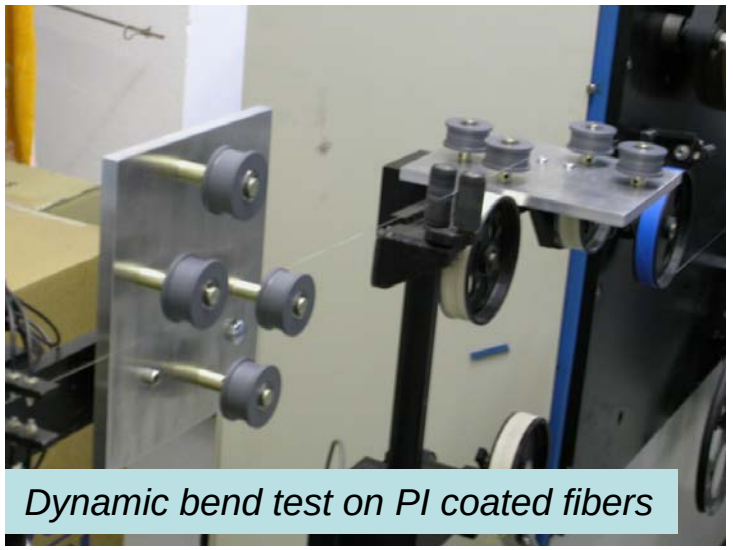
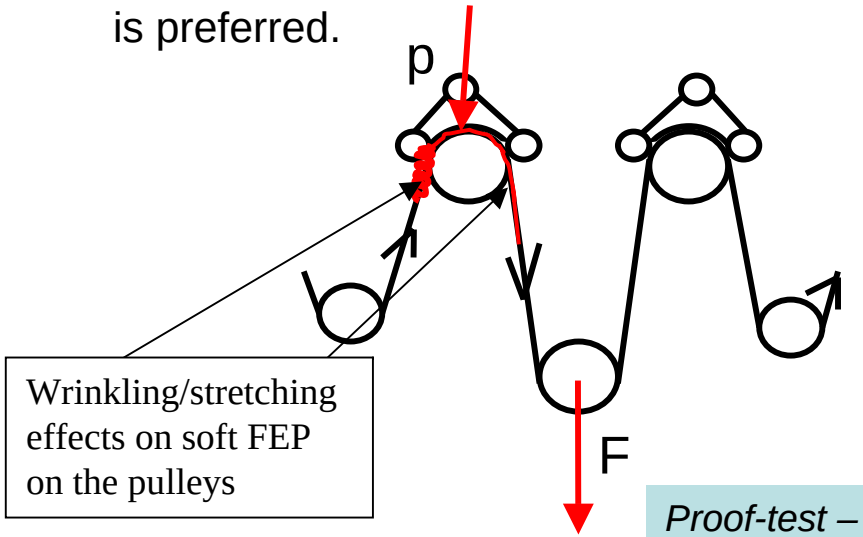
I) On a fiber with soft outer FEP coating and rather stiff inner PI coating, an execution of a conventional Proof-test turned out to be inadequate.
The additional Proof-test (refer to p.7) damaged a part of the remaining fiber in a way that it could no more used.

Reason: In case of pressure application during Proof-test, stretching of the FEP on one side of the “take-on/off”-roll leads to a wrinkling on the opposite side and to micro bending stress on the fiber core.
Thus, a Proof-test, if any, on FEP coated fibers must be performed under very low pressure. A so-called dynamic bend test is preferred.



Dynamic bend test on PI coated fibers



Proof-test – sketch

Summary, Measures

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Supposed contributing effects leading to the one fiber break:

Slight damage of the outer coating during handling and/or

Undergone bending radius just before break

Also stress corrosion cannot be fully excluded.

Note that there is no 100% prognostication of fiber break or fiber survival, only statistic statements.

Measures to avoid further fiber break:

- **Simplified mounting procedure for fibers on further ATV**
- **Careful fiber cable handling, avoidance of “over-handling”**
- **Check of the already mounted cables by a magnifying lens**
- **Introduction of a mechanical protection on ATV to avoid fiber damage**
- **Dynamic bend test for cable assembly, and instead of Proof-test**
- **Optimization of fiber design and procedures in case of further fiber manufacturing (e.g. coating material, test methods)**

Conclusion

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A lot of investigations were performed, specialist of ESTEC and of fiber manufacturing companies were involved

There was no indication of a significant systematic error in the fiber design, that could provoke further fiber break during lifetime of the cables

The most probable error cause is a combination of handling errors

A number of measures was defined to mitigate the risk of further fiber break

Sincere thanks to all who supported us during the investigation works after fiber rupture