Robotics & Airlock Accommodation Study for Columbus

Advanced Space Technologies for Robotics and Automation 'ASTRA 2000'

Herbert Schwartz
Astrium
Herbert.Schwartz@astrium-space.com

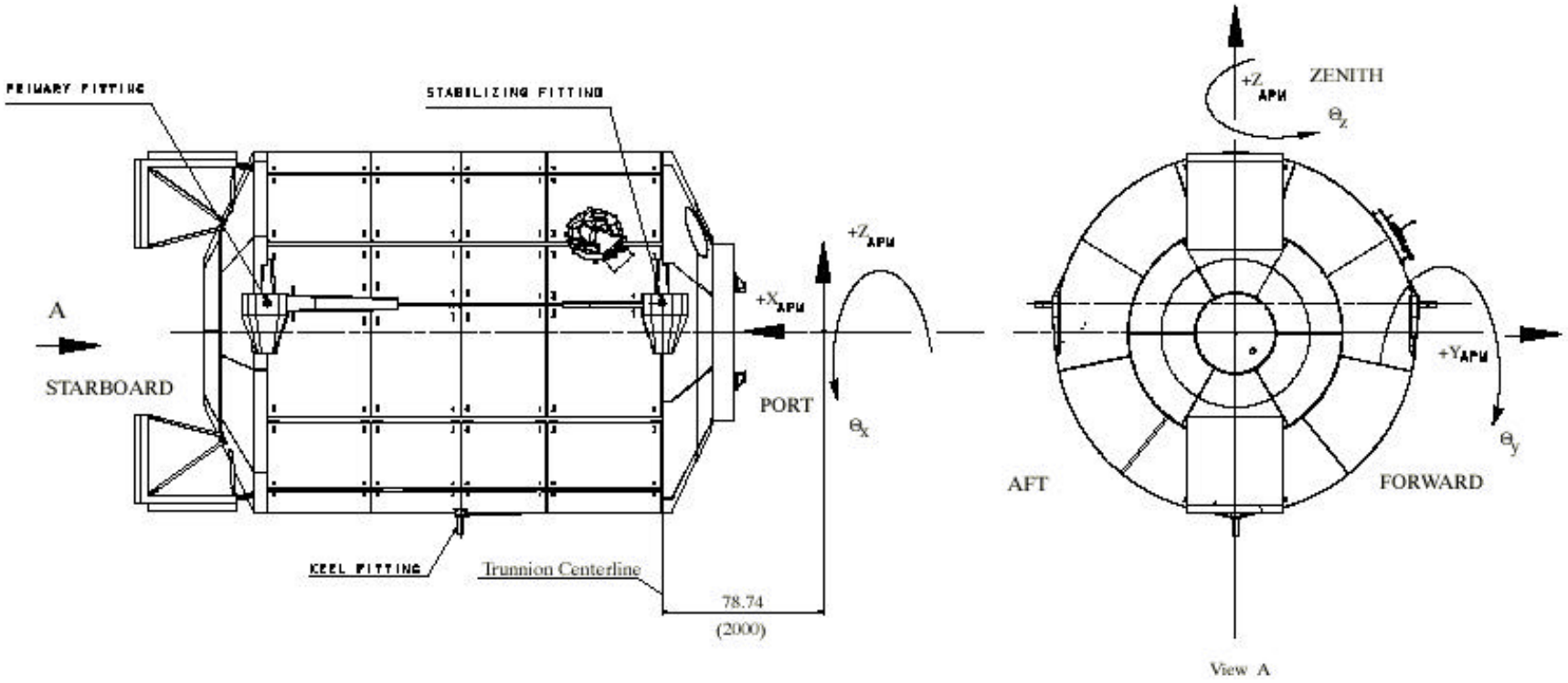
Scott Hovland
ESA
Scott.Hovland@esa.int

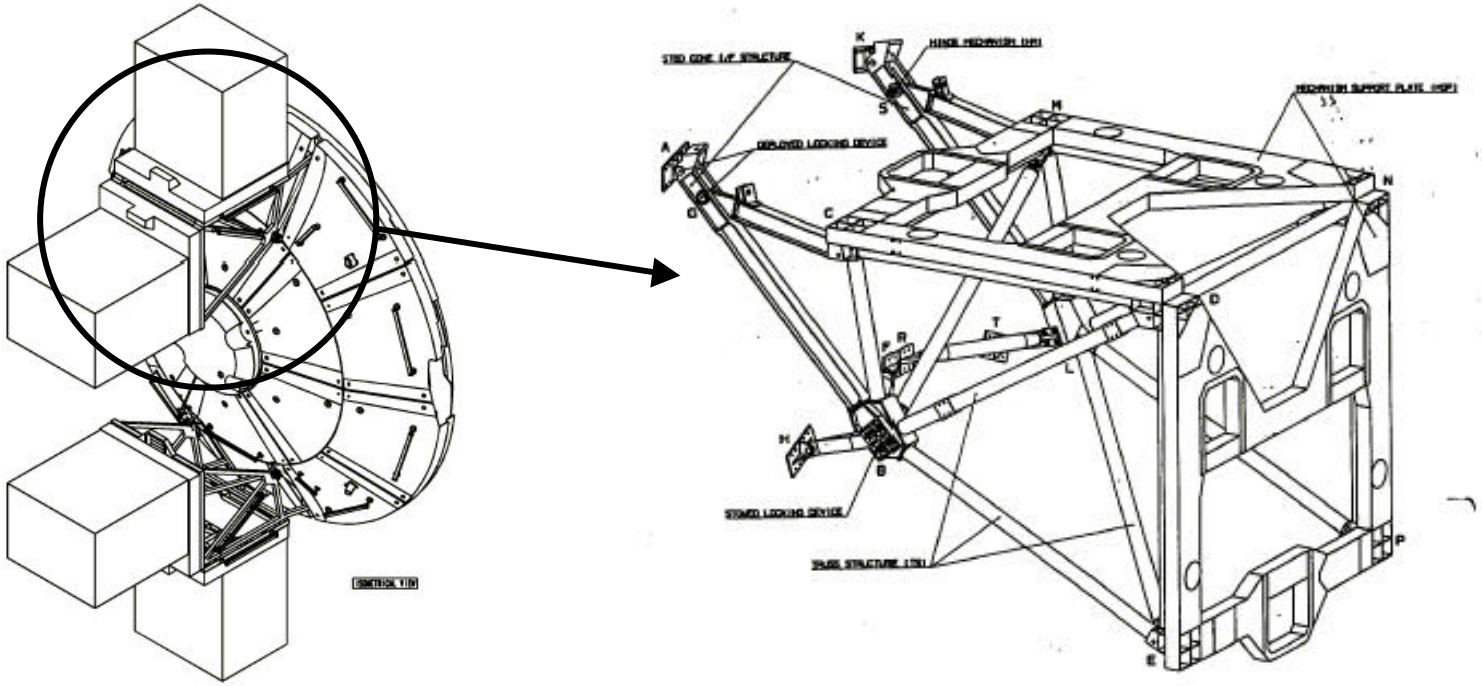
- **The baseline scenario for external unpressurised payloads on the Columbus External Payload Facility (EPF) foresees the transport of Payloads on an Express Pallet Adapter (ExPA) launched by the Space Shuttle.**

- **This Pallet Adapter, which is fitted with fully self-sufficient individual payloads, is then moved to the EPF on the Columbus end-cone with the help of the ISS robotic arm.**

- **Present ESA planning for the use of the ISS is based on the transport of one Pallet Adapter per year. If two of the available four locations are used by the European User community, the average time in orbit of the experiments is two years.**

- **Improvements of this very restrictive operating scenario appear possible:**
  - By placing a robotic manipulator on Columbus or on an ExPA capable of serving two or four adapter locations:
    - The robotic manipulator on the ExPA increases flexibility by allowing re-configuration of payloads, re-location, inspection etc.
    - Placing the manipulator as an infrastructure element on Columbus, would improve the effective P/L to total mass ratio for the transport. This would come in addition to the flexibility available through the permanent presence of the manipulator.
  - By fitting an airlock into the Columbus end-cone in addition to the manipulator
    - The availability of an airlock could further improve flexibility and services to users by allowing the external placement of experiments that are transported by pressurised means.


PRIMARY FITTING
STABILIZING FITTING
A
STARBOARD
+X APM
+Z APM
PORT
θx
KEEL FITTING
Trunnion Centerline
78.74
(2000)
+Z APM
ZENITH
θz
+Y APM
θy
AFT
FORWARD
View A



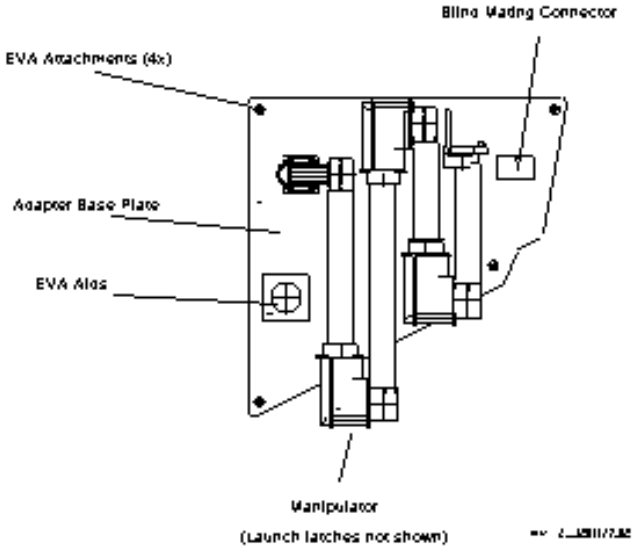
- **This study (performed by Astrium, Alenia Spazio and Fokker Space) has addressed:**
  - Accommodation options of a robot and its associated avionics
  - Accommodation possibilities of a small, mechanical airlock in conjunction with a robotic system
  - Operational scenarios, logistics and maintenance of payloads as well as the robot system and airlock
  - Launch options for the robot (on flight 1E or later flight)
  - Installation of the robot (on ground / on orbit robotic / EVA)
  - Control of the robot via commands initiating automated procedures, both from ground and on orbit
  - Columbus impacts w.r.t.
    - Necessary modifications to the current design
    - Verification
    - Schedule & Cost
  - P/L operation impacts

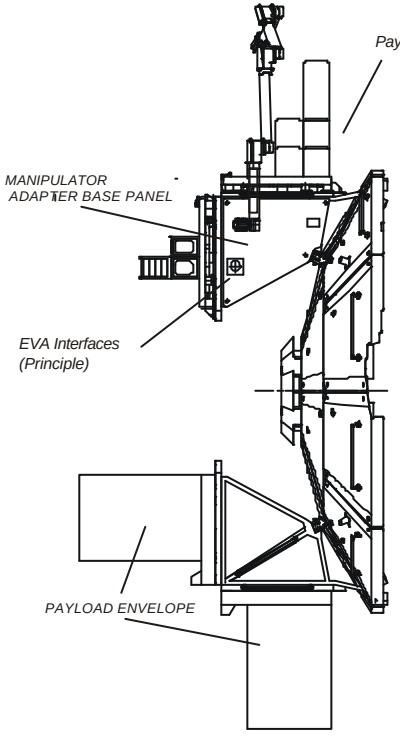
- **Several robotic concepts were studied to find out which configuration would have the best performance (e.g. reach, size, launch possibilities, control) with the least impact to Columbus**

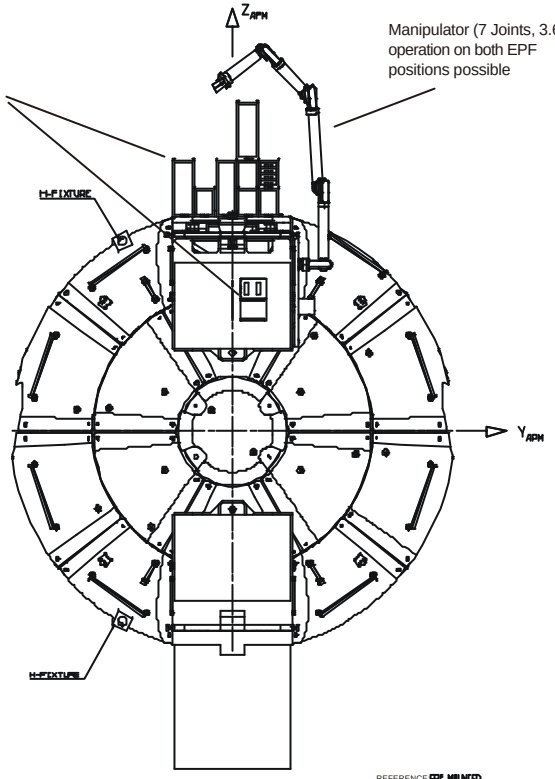
- **The following three were selected as a basis for the full impact analysis**
  - EPF Mounted Manipulator
  - Manipulator on EPF Mounted Rail
  - Manipulator on an ExPA in a P/L Position

- **The remaining concepts were not studied in full either due to large impact without added benefit or similarity to one of the other concepts**

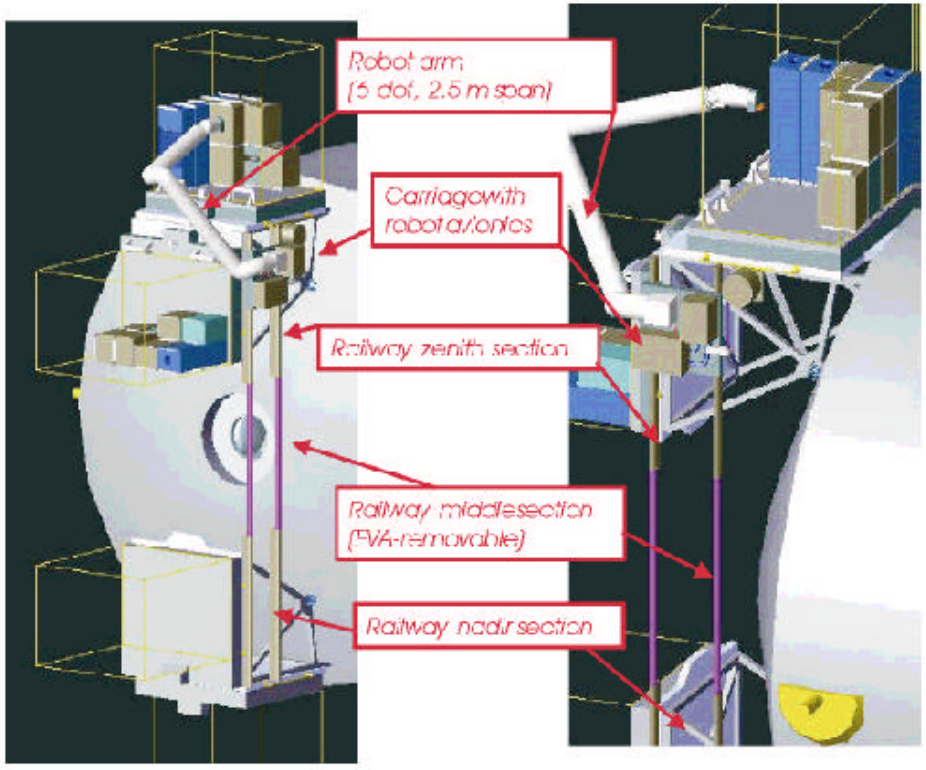
- **APM with Robotics and Airlock**
  - Robotics integrated as S/S
  - Fixed mounted on side of EPF with access to two ExPAs and airlock or relocateable to other EPF





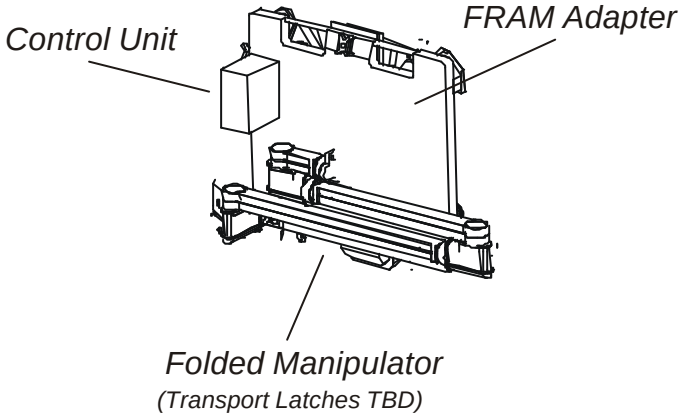


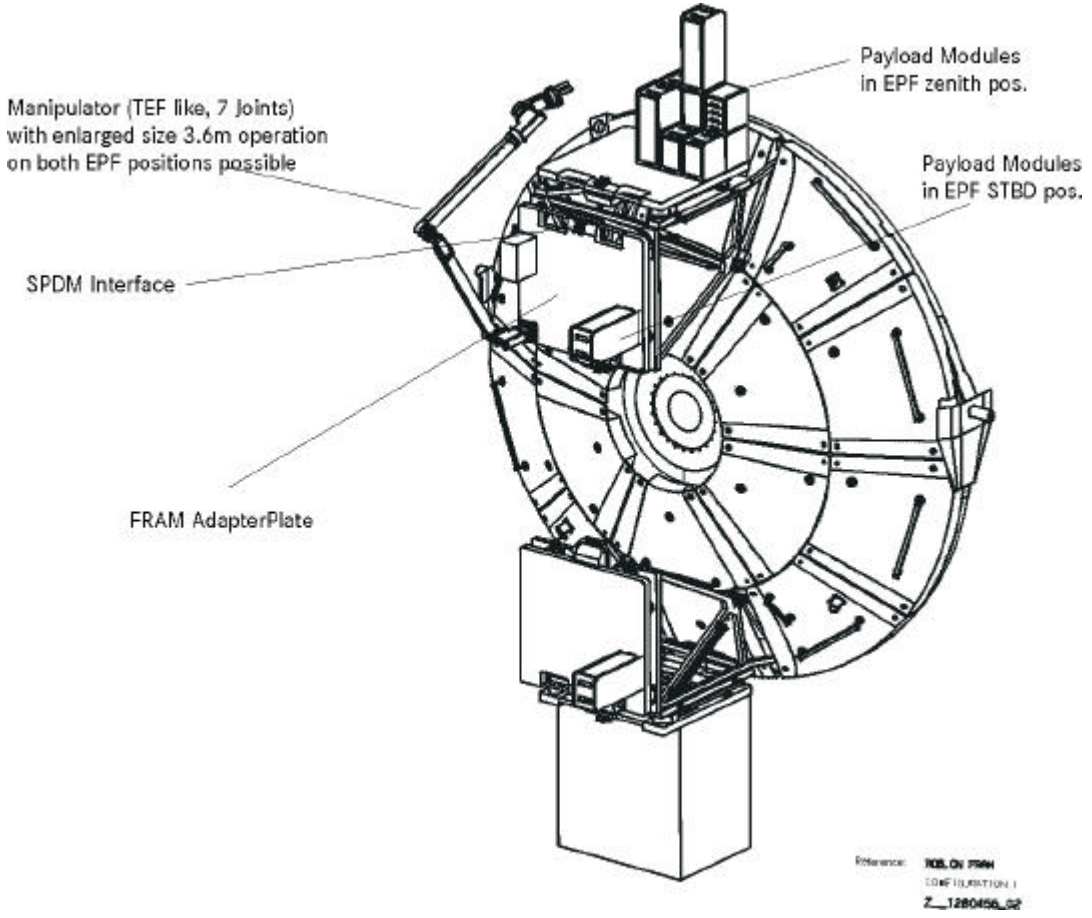
- **APM with Rail Mounted Robotics and Airlock**
  - Robotics integrated as S/S
  - Mounted on side of EPF with rails connecting the two platforms
  - Access to all four ExPAs and airlock



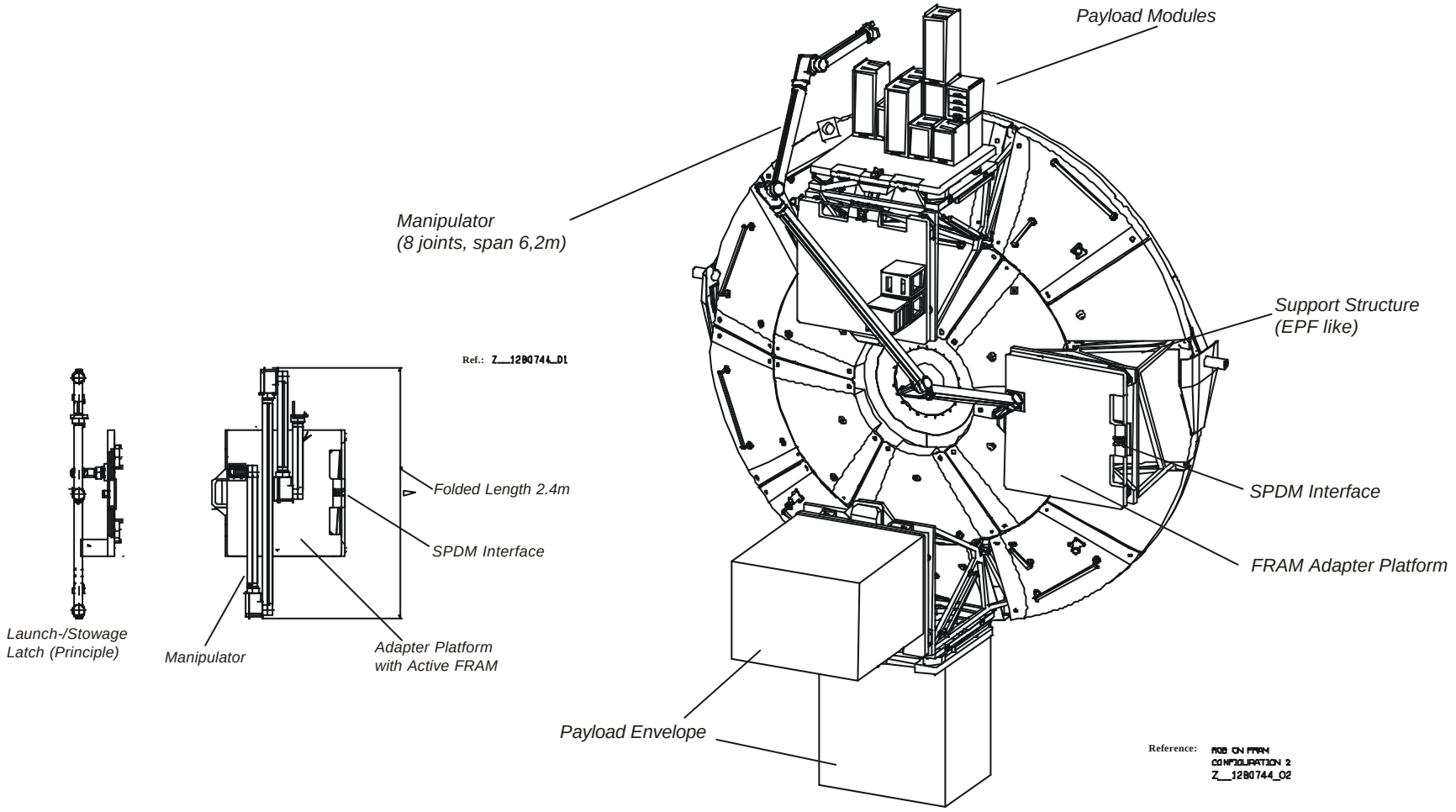
Manipulator on an ExPA in a P/L Position

- **APM with Robotics only (EuTEF type)**
  - Robotics integrated as P/L

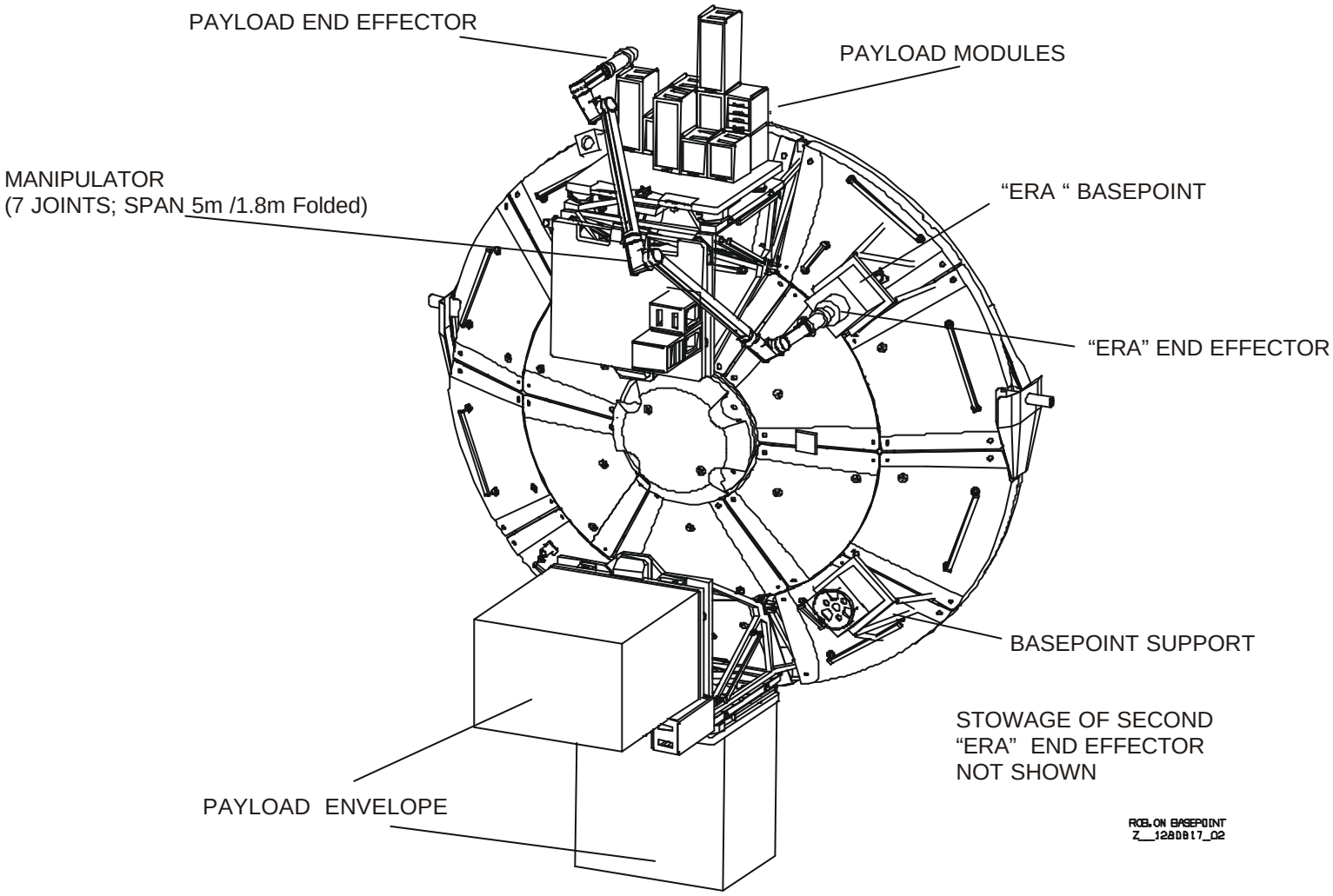




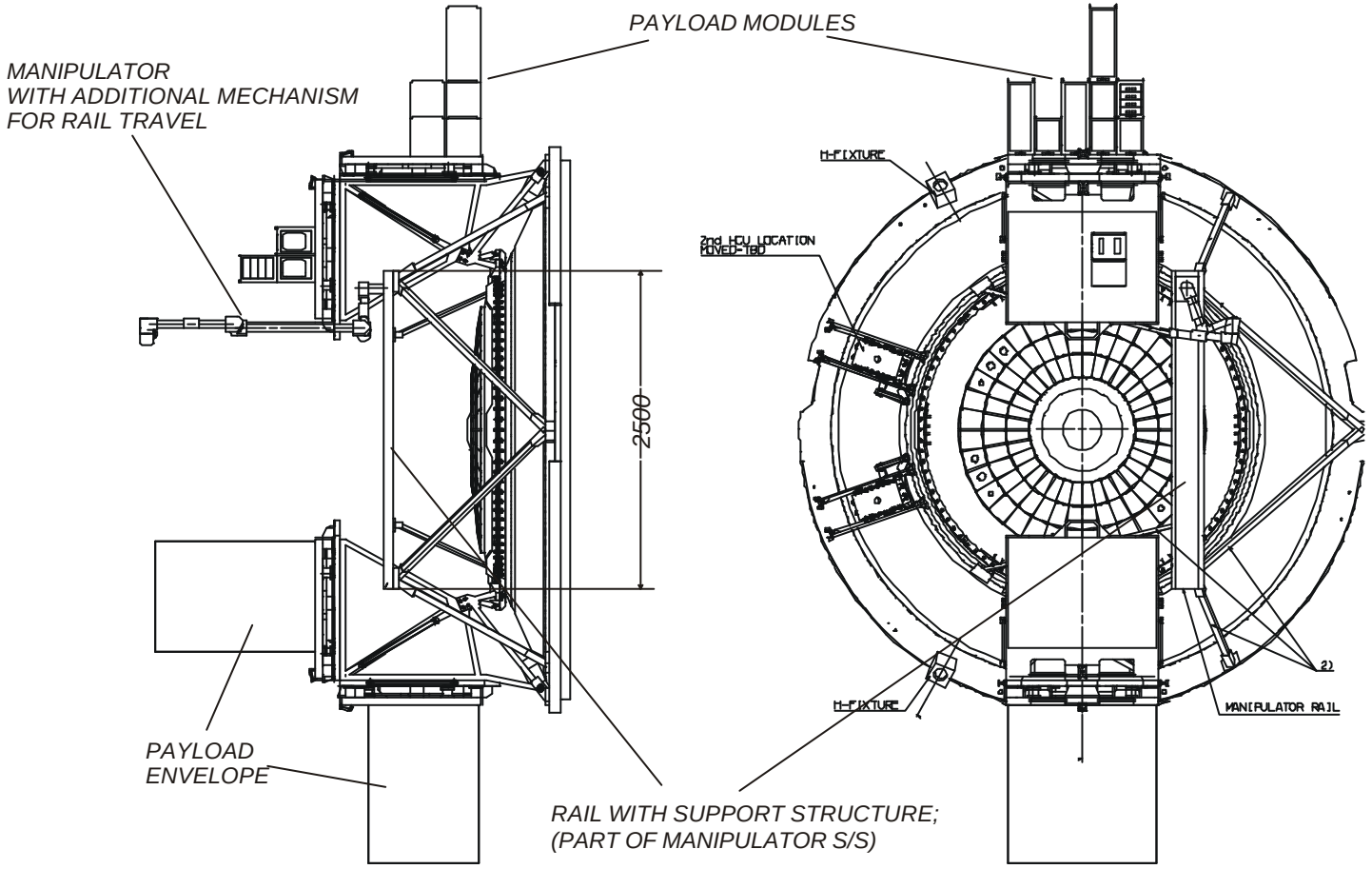
Manipulator on Separate FRAM Mount



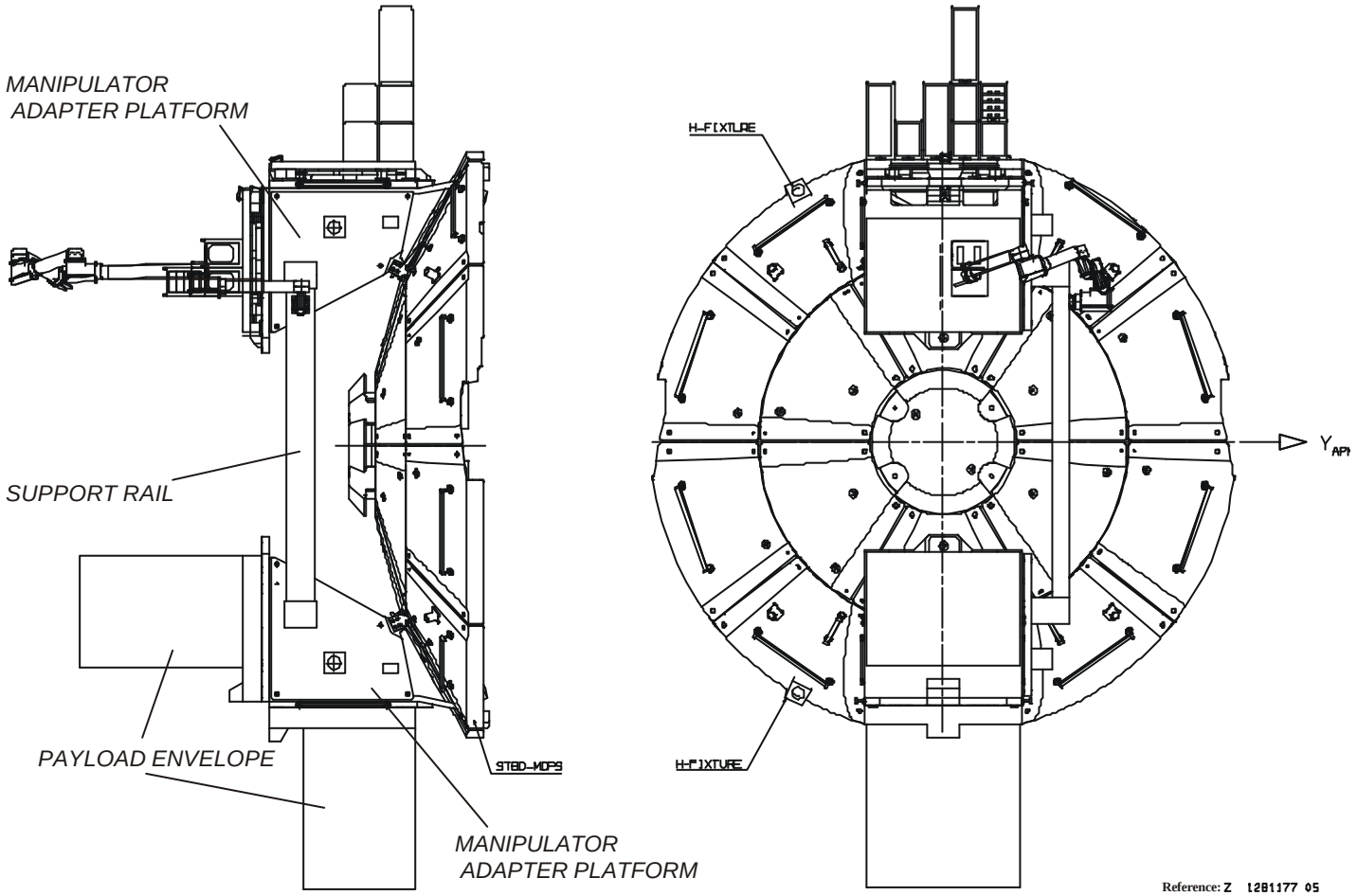
ERA- like Model with Two Basepoints



Manipulator on Cone Mounted Rail



Manipulator on EPF Mounted Rail



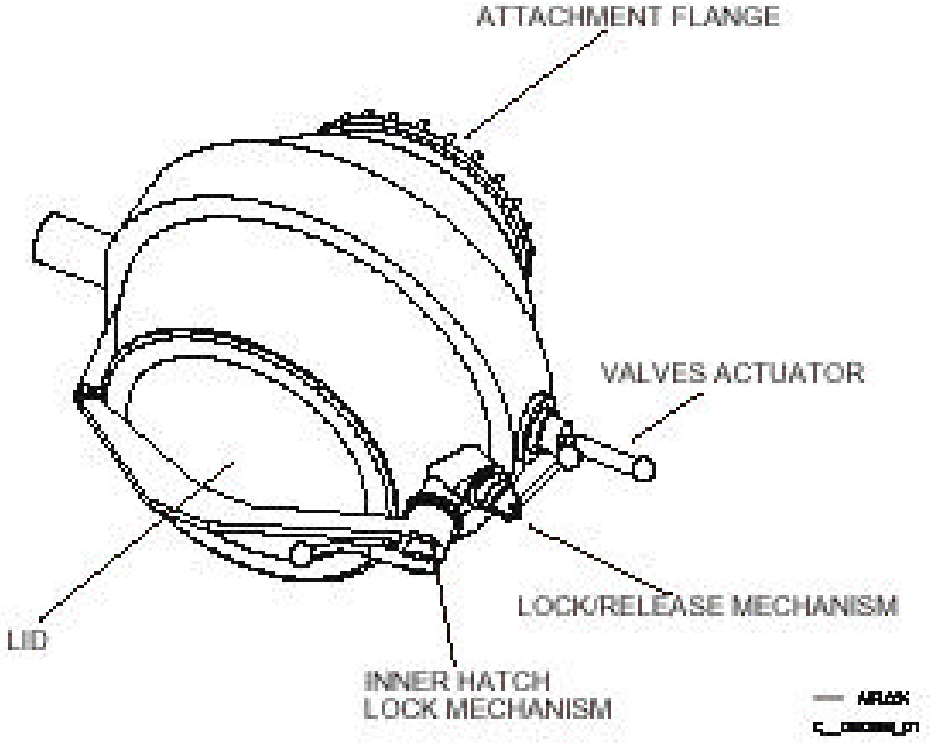
- **The avionics location options (internal vs. external) were assessed with respect to the criteria:**
  - Electrical Performance
  - Joint Torque
  - Thermal Control
  - Harness Design
  - Accommodation Constraints
  - Feasibility of Rail Drive

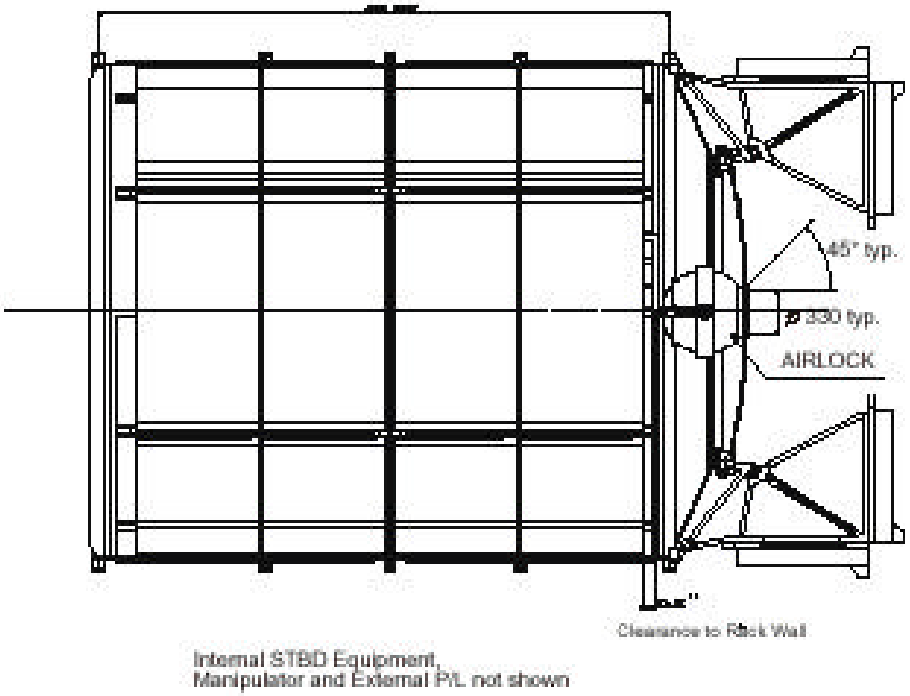
- **The results are shown in the following comparison table, using the criteria suitable/feasible, suitable/feasible with restrictions, and not feasible, (correspondingly indicated by the background colours blue, yellow, and red).**

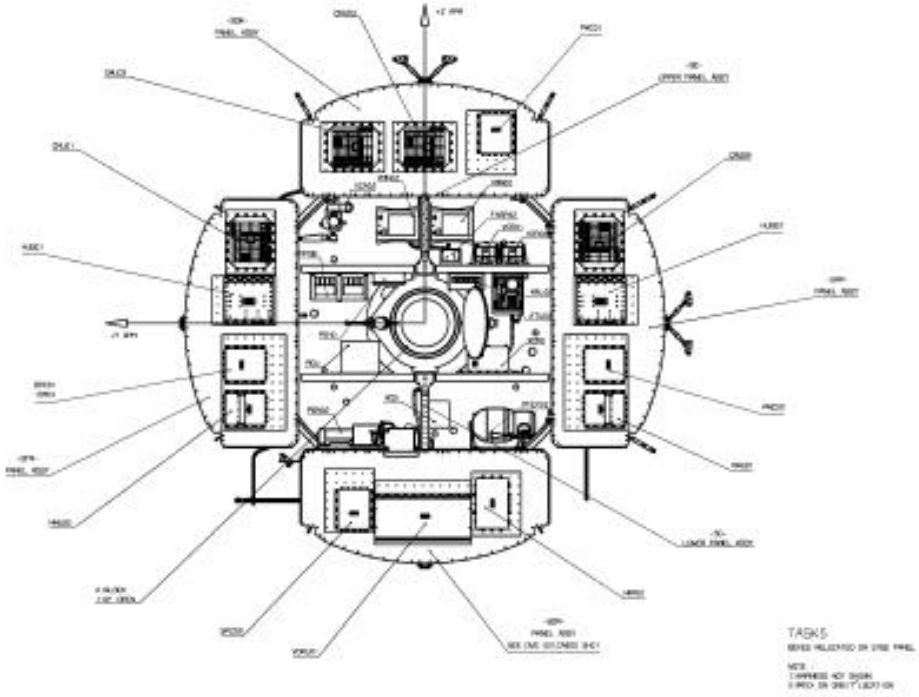
Options -> Evaluation criteria	1) Analogue Circuitry Control		2) Bus Controlled System	
Avionics Loc.	a) internal	b) external	external	internal
Electrical performance	limited; extremely long signals/power transmission paths	limited by lengths of signals/power lines	high, shortest transmission length for power and signals	high, shortest transmission length for power and signals
Joint torque	limited	limited	high	high
Thermal Control	APM standard	radiator / heater accommodation, use limited	radiator / heater accommodation, use limited	APM standard
Harness Design	harness consisting of ~ 200 connections	harness consisting of ~ 200 connections	Particular Lines (Data Bus,Power, Discrete Lines)	Particular Lines (Data Bus,Power, Discrete Lines)
APM Accommodation	Harness length < 5m not feasible	feasible for TEF-like model or bus to internal RCU not feasible in cone area	feasible for TEF-like model or bus to internal RCU not feasible in cone area	feasible
Rail drive	not feasible, Stiff wire bundle	not feasible, Stiff wire bundle	feasible	feasible

- **The Krunichev PELIKAN Airlock as flown on MIR was the only viable airlock available for consideration**
- **Other airlocks were either too large to be accommodated or in an early stage of development**

- **Dimensions**
  - Length 790mm
  - Flange ∅ 468mm
  - Mass 96 kg




45° typ.
ø 330 typ.
AIRLOCK
Clearance to Rack Wall
Internal STBD Equipment,
Manipulator and External P/L not shown



- **The availability of a Robotics Manipulator / Airlock was shown to improve the operational scenario:**
  - Reduction of experiment turnaround times and increase in experiment opportunities because of pressurized carrier use
  - Shortening of experiment preparation by using standard Small P/L Modules needing less launch integration preparation, with later access to launch vehicles
  - Access to ISS infrastructure use, e.g. final Preparation of Biological samples in MSG, or fixation after exposure, use of Refrigerator/Freezer

- **The study results by Astrium show that:**
  - The implementation of a Robotics facility and Airlock on Columbus is technically feasible
  - The schedule scenario with robotics and airlock implementation was shown feasible in the frame of the present Columbus C/D schedule
  - The estimated operational/logistics cost saving partly counterbalances the significant investment which is needed for the Robotics and Airlock implementation
  - A low cost model is feasible with Robotics alone as External Payload, needing no APM modifications
  - In addition to the operational/logistics benefit, there is a scientific and utilization benefit for the External Payload

ESA Conclusions

- **ESA**
  - has reservations to the schedule and judge the associated risk for implementation of a robotic facility together with an airlock too high
  - judges the investment costs for the Robotics and Airlock implementation to be very high compared to the estimated operational / logistics cost saving

- **The conclusion reached is to:**
  - Develop a robot/manipulator to be flown as a payload and demonstrated on board Columbus
  - The robot to make use of most advanced robotic technologies (e.g. ground control / tele-commanding)
  - Lessons learned from flight could to be used for operational improvements of the robot with possible re-flight later
  - Technology demonstrated can lead to improved robotics operation on the ISS as well as provide robotics experience for future planetary exploration