EUROPA

External Use of RObotics for Payloads Automation

by:

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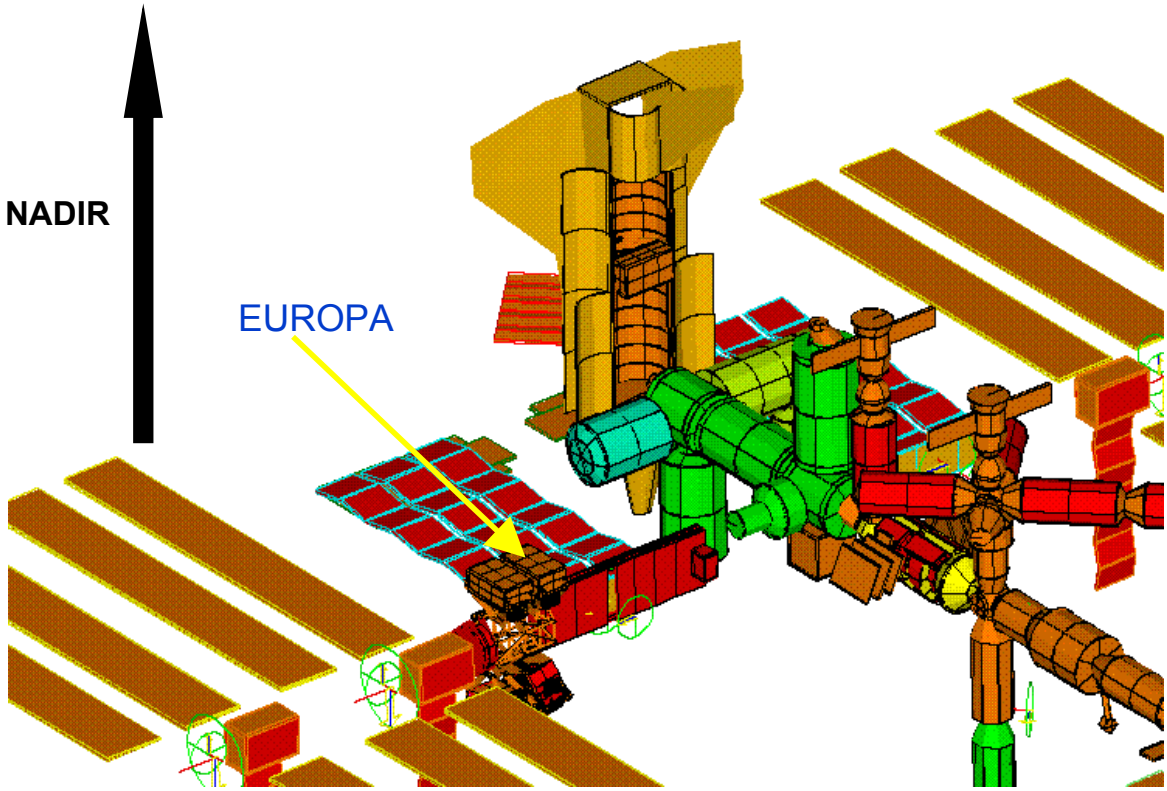
ASTRA 2000 Workshop, ESTEC, December 5-7, 2000

EUROPA Description

- EUROPA is a payload proposed by ASI (Italian Space Agency) in cooperation with ESA (European Space Agency), which aims at
  - performing a realistic end-to-end robotic technology demonstration
  - providing a robotic system for installation, removal, handling, manipulation, servicing and inspection of externally exposed payloads
- it will be accommodated on one of the six adapters of an EXPRESS Pallet on the S3 truss
- it is scheduled to be flown on UF3 (September 2004)
- it is based on the experience gained in the frame of ASI/ESA projects (SPIDER, JERICO, etc.)

EUROPA Location on ISS



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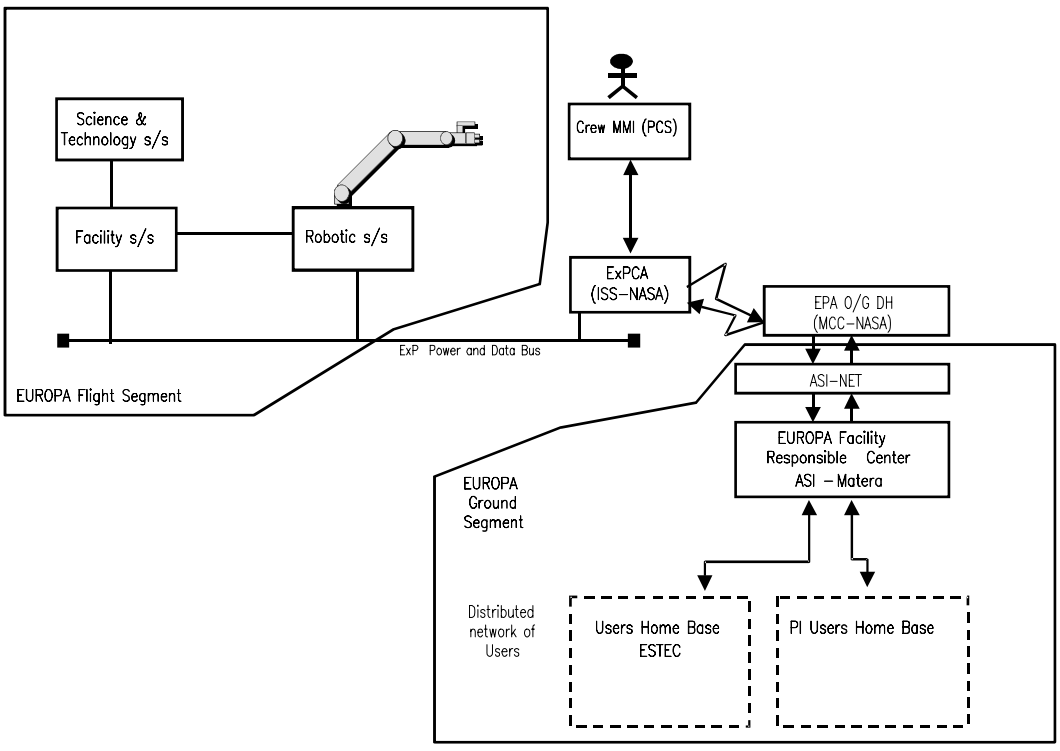
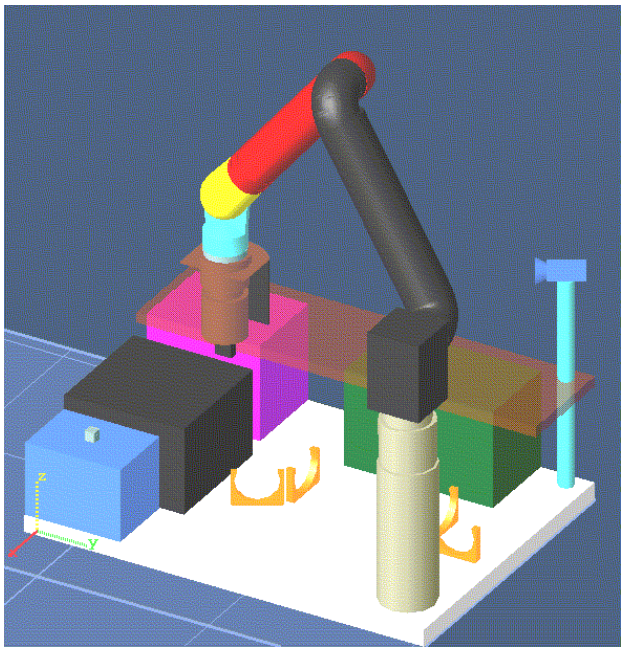
EUROPA System Overview



EUROPA Flight Segment



- Robotic S/S
  - arm
  - hold down mechanism
  - end effector
  - force/torque sensor
  - robot calibration platform
  - controller
- Facility S/S
  - data handling and power unit
  - video monitoring unit
  - thermal control elements
  - harness
- Science & Technology S/S
  - taskboard
  - science payload
- Crew MMI SW

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EUROPA Experiments

- Robot system characterisation and robotic technology demonstration
  - the taskboard will be used to evaluate/measure the performance capabilities of the arm
    - force & torque checkout unit; to verify the F&T measurement against a well-known spring characteristic
    - laser diode unit(s) with beam splinter used for the EUROPA in-orbit performances verification and eventual calibration needs
- Science payload investigation
  - the science payload consists of an experiment aiming to measure diffusion and Soret coefficients of liquid mixtures. The payload will benefit the basic manipulation capabilities (sample transfer) from EUROPA robot manipulator

EUROPA Operations

- Preparation
  - all operations will be pre-programmed and verified on ground using an off-line programming system and the Ground Reference Model (a ground replica of the Flight Model)
  - the resulting activity plan will be a set of hierarchical activities consisting of tasks and actions, which will be uploaded on the flight robot controller
- Execution
  - execution of the activity plan under ground control (access to the TM/TC channels is assumed to be available) or under on-board MMI control (crew PC), either in autonomous or interactive mode
  - possibility to intervene and correct in case of anomalies ("interactive autonomy")
    - immediate stop of the current execution at any time
    - resolve the anomaly
    - resume the experiment or perform nominal or non-nominal stowage
- Post-operation
  - exploitation of TM data using the ground segment, for system performance analysis

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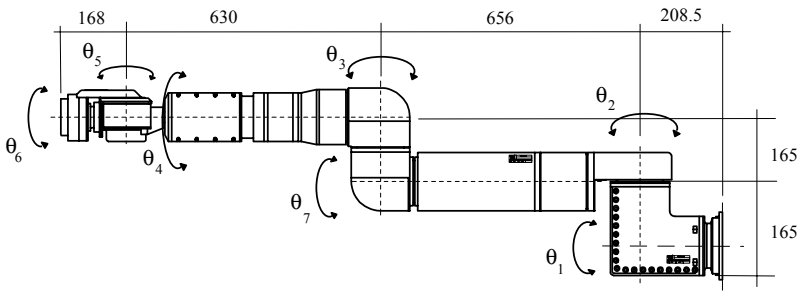
EUROPA Main Capabilities

- Reach of manipulation for payloads mounted on the ISS Express Pallet
- Contact-free positioning of grasped objects
- Contact operations (compliant motion control with completion by force or position, applied force torque capabilities)
- Inspection capabilities (close-up imaging of selected items on the adapter) via RCP camera and payload pose acquisition with a given accuracy
- Execution and control of programmed servicing operations for payload servicing (tasks and actions), with possibilities to start, stop, suspend, resume
- Command input and data exchange with the EUROPA ground segment and crew MMI (PCS)
- Data handling and storage (video image data, scientific data, robotic data, calibration data, on-board SW and application programs)

Robotic Arm (SPIDER)

- Anthropomorphic arm featuring 7 rotational degrees of freedom
- Divided into three subsystems (shoulder, elbow, wrist) by means of two dedicated latching/delatching mechanisms
- Each joint is powered by an electromechanical actuation group composed of motor, gearbox, input and output shaft position sensors (resolvers) and brake



Actuation force: 25 N (100 N short period < 10 s)
Accuracy: < 3 mm
Repeatability: 1 mm
Maximum speed:
- linear 0.1 m/s,
- rotational 0.1 rad/s

Mass: 60 Kg

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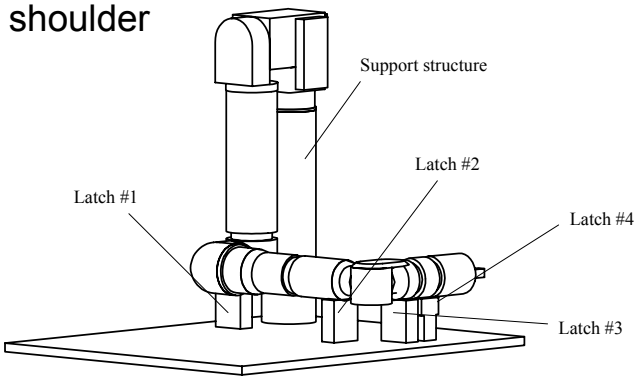
End Effector, Force/Torque Sensor and Robot Calibration Platform

- End Effector
  - general purpose, composed of two jaws, equipped with tactile sensors
  - opening width from 0 to 76 mm, grasping objects up to 70 mm, with a maximum grasping force of 300 N
- Force/Torque sensor
  - strain gauge type, range 200 N / 20 Nm, resolution 0.1 N / 0.01 Nm
- Robot Calibration Platform (RCP)
  - position sensing devices (laser), CCD camera plus lens

Hold Down Mechanism

- Automatic mechanism to hold the arm during launch and landing phases
  - four latching clamps
    - elbow
    - forearm
    - wrist
    - RCP, Force/Torque Sensor and End Effector
  - support structure to fix the shoulder



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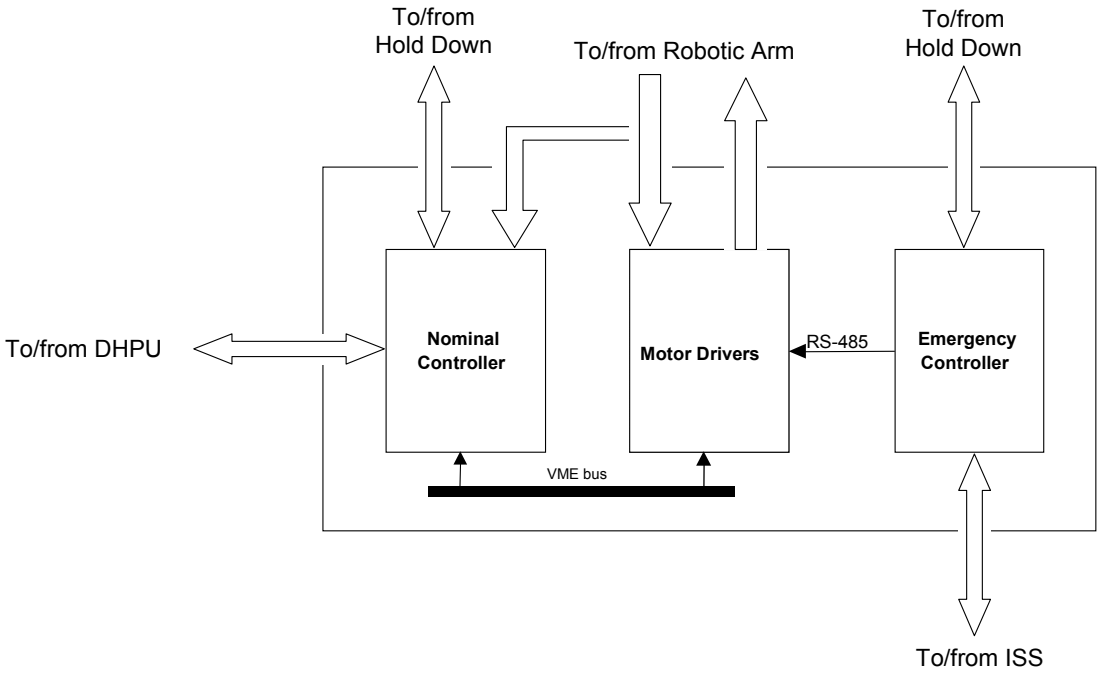
Data Handling and Power Unit

- Handling of TM/TC communication interfaces between the Europa Facility and the ISS
- Activation and supervision of the Europa robotic mission
- Monitoring of critical parameters (e.g.: temperature) and resources (e.g.: power, data rate) consumption
- Handling of TM/TC communication interfaces with the Scientific Payload, the Taskboard , the RCP and the Robot Controller
- Acquisition and down link of images from RCP and VMU cameras
- Distributing operational / stay alive and contingency power lines to all units of the Europa Facility, including heaters

Controller Block Diagram



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Nominal Controller

- Robot programs interpretation, in compliance with the I/F to the EUROPA MMI Ground Station based on the SPARCO library concepts and the Control Development Methodology (CDM, the ESA standard for Automation & Robotics development)
  - tasks (such as INSPECT, ACTUATE, OPEN, CLOSE, INSTALL, REMOVE)
  - actions (such as displace to, move along, approach / retract from, attach / detach, insert / extract, hinge, push, slide, apply-force, relax-force)
- Trajectory planning and generation (Cartesian and joint motion)
- Sensor based control, to achieve coordinated motion of the end effector in free space and in contact with the environment
  - internal sensors such as resolvers
  - external sensors on the end effector, such as force/torque and tactile sensors
- Inverse kinematics, with arm redundancy management
- Control the hold down mechanism, to latch/unlatch the arm in its stowage configuration

Emergency Controller

- It intervenes to fold the arm when there is one failure on the nominal chain (nominal controller and/or data handling and power unit) that cannot be recovered
  - directly connected with the ExPA + 28 Vdc power line to distribute power to motor driver and hold down
  - directly connected to the ExPA 1553 line for communication
  - transmission of commands to the driver via serial line allowing for the direct drive control of the arm joints (motion of a single joint at a time with small steps)
  - use of cross-strapping features of the drivers, if needed
  - control of the hold down mechanism, to latch/unlatch the arm in its stowage configuration
- This will minimise astronaut EVA intervention

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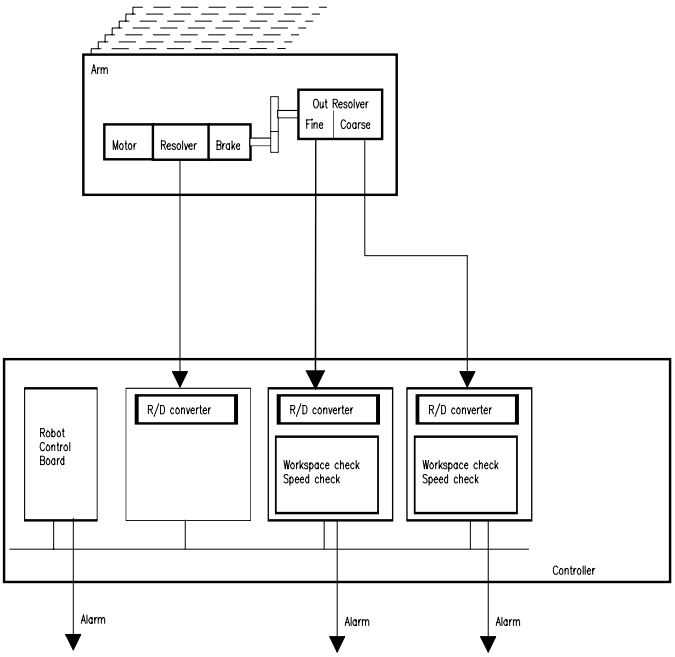
Motor Drivers

- Drive the robotic arm/end effector motors and brakes, by providing four boards (each one dedicated to two joints)
  - receive motor current setpoints from the controller
  - perform motor resolver acquisition
  - provide motor commutation function, by generating two-phase current reference vectors
  - perform current loop and provide power drive to the motors
- Nominal mode
  - commands will be received from the nominal controller via VME
- Emergency mode
  - commands will be received from the emergency controller via serial line
  - it is foreseen to drive one joint motor at a time
  - in case of failure on one driver board, a given joint can be moved by another board, by means of cross-strapping circuitry

Safety



- Collision effects
  - overcurrent safety barriers (dedicated hardware on the motor drivers)
  - overspeed safety barriers (computer based control system fail safe approach)
- Arm outside of defined workspace
  - workspace limitation safety barriers (computer based control system fail safe approach)

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Conclusions

- The EUROPA system, based on a medium-sized robotic arm, aims at providing
  - a realistic end-to-end robotic technology demonstration to show the advantages and the feasibility of a versatile robotically tended exposure payload infrastructure
  - a rapid and reliable logistics support for scientific experimentation on the ISS, able to perform manipulation activities for payload operations, without the need for human Extra-Vehicular Activity