

# An Overview of Mission Applications for Space A & R

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## Space Robotics: Overview of Application Scenarios

- LEO applications = ISS applications
  - system servicing, robotic assembly of spacecraft
  - payload tending
  - free flying inspection and servicing
- Robotic satellite servicing in GEO
  - ETS-VII flight demonstration
  - experimental / operational systems
    - ◆ renewed interest in ESA, EU, D
- Robotics for surface exploration in Solar System
  - clearly rising in priority (new ESA Science cornerstone mission to Mercury !)
  - Moon, Mars, Mercury: Session 1.2
  - comet sampling (Rosetta): presented in ASTRA 98, under development

## Robotic System Servicing on the ISS (1)

- Large robot systems for ISS assembly and servicing
  - Canadian MSS (Mobile Servicing System) on Western Segment
    - ◆ extensively presented in ASTRA 98, iSAIRAS 99
    - ◆ recap of SPDM design features: exhibit
    - ◆ update on verification approach: papers 2.2-1, 2.2-2
    - ◆ new: ground control ?! (paper 3.4-3)
  - ERA (European Robot Arm) on Russian Segment
    - ◆ extensively presented in previous ASTRAs and iSAIRAS 99
    - ◆ test results, lessons learnt: Session 2.1 (3 papers)
    - ◆ technical visit to Fokker on Thursday pm !
    - ◆ ERA Evolution: lacking political support so far

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## Robotic System Servicing on the ISS (2)

- Assembly and servicing of other spacecraft from the ISS
  - XEUS ("next generation XMM")
    - ◆ scenario and concepts presented at ASTRA 98, iSAIRAS 99
    - ◆ no new results on robotics aspects, thus no dedicated presentation at ASTRA 2000
  - Status of XEUS mission and system development:
    - ◆ first system study for ISS accommodation completed in 1999
    - ◆ critical role of robotics confirmed (unique cooperation of Shuttle RMS / SSRMS / ERA !)
    - ◆ very high interest from both Science and Space Station
    - ◆ second system study initiated in Q4/00
    - ◆ scope: investigate detailed technical design characteristics incl. ISS interfaces
  - Dedicated robot technology developments:
    - ◆ TRP "Robotic Assembly of Large Space Structures" initiated in 2000
    - ◆ see presentation P. Putz on ESA R&D, paper 1.3-1

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### Robotic Tending of Payloads on ISS (1)

- Tending of externally-mounted payloads (EVA robotic tending)
  - JERICO on Russian Segment of ISS (see ASTRA 98)
    - ◆ cooperation with Russia had to be abandoned
    - ◆ ESA technology developments validated in JET (end-to-end JERICO Evaluation Testbed): paper 3.4-1, live demo
  - TEF / EuTEF on Western Segment of ISS/ EXPRESS pallet (ASTRA 98, iSAIRAS 99)
    - ◆ cooperation with ASI, DLR on robotics did not materialise - EuTEF now developed as non-robotised facility
  - EUROPA on ISS / EXPRESS pallet (see iSAIRAS 99)
    - ◆ cooperation ASI / ESA for flight in 2003 (new incarnation of JERICO / robotised EuTEF)
    - ◆ mission and system update: paper 1.1-2, ground segment: paper 3.4-2
  - New: ExtRoTEF for Columbus External Payload Facility
    - ◆ D/MSM system study "Columbus External Robotics" completed: paper 1.1-3
    - ◆ DLR study on possible contribution of robot system completed

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### Robotic Tending of Payloads on ISS (2)

- Tending of internally-mounted payloads (IVA robotic tending)
  - PAT (Payload Tutor) in ISS pressurised labs:
    - ◆ presented at ASTRA 98, iSAIRAS 99 (cooperation ASI / ESA)
    - ◆ interest is still there
    - ◆ to be tackled after external p/l tending (manpower and funding limitations)
    - ◆ technology developments ongoing (e.g. simplified on-board controller h/w for pressurised environment)

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### Free-Flying Robotic Inspection and Servicing

- many approaches and system studies presented in ASTRA 98
  - ATV enhancements, Free-Flying Micro Operators (FFMO), ISS-Inspector, SPIDER (SPace Inspection Device for External Repair)
  - no success so far in establishing such a system as a European contribution to the ISS
    - ◆ too much too fast ?
    - ◆ strong NASA reservations w.r.t. safety and influence
- Japanese ETS-7 mission (iSAIRAS 99)
  - demonstrated capabilities and feasibility of free flying robotics
- ISS inspection scenario not actively pursued in ESA now
  - not under European responsibility
  - other means exist (EVA) ?
- Scenario may come back soon
  - first studies have established higher criticality of impact damage in ISS hulls

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### Robotic Satellite Servicing in GEO

- in-orbit demonstration mission: Japanese ETS VII (98/99)
  - very successful
    - ◆ technically
    - ◆ in terms of international cooperation
  - Japanese and European experiments extensively presented at iSAIRAS 99
  - DLR experiments: paper 2.2-3
- new experimental / operational systems
  - renewed interest !
  - Germany: capture / retrieval mission of ROSAT satellite ?
    - ◆ studies performed in 2000
  - ESA / EU: maintaing the GEO orbit safe and performant
    - ◆ initiated at General Study level (ROGER = RObotic GEostationary orbit Restorer)
    - ◆ see presentation P. Putz on ESA R&D (paper 1.3-1)

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### Robotic Surface Exploration in Solar System (1)

#### ● Mars surface science / exploration

- ▶ Mars Express mission
  - ◆ approved ESA mission, launch 2003
  - ◆ robotic arm for Beagle 2 lander: paper 1.2-2
  - ◆ sampling mole: paper 3.5a-3
- ▶ exobiology research
  - ◆ D/MSM study on multi-user facility with A&R completed: paper 1.2-3
  - ◆ specific technology development: robotic "deep" drilling system (paper 3.5a-4)
- ▶ robotic micro science laboratory (IPSE)
  - ◆ for bilateral cooperation ASI / NASA: paper 3.5a-2
- ▶ rover work at CNES
  - ◆ autonomous navigation technology for bilateral cooperation CNES / NASA: paper 3.7-3
- ▶ Mars micro rover work at ESA (ASTRA 98, iSAIRAS 99)
  - ◆ Nanokhod micro rover: exhibit, demo; control: paper 3.7-1

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### Robotic Surface Exploration in Solar System (2)

#### ● Moon surface science / exploration

- ▶ still some international interest (Japan, USA)
- ▶ possible robotics applications for Europe: paper 1.2-1

#### ● Human missions to Mars / Moon

- ▶ strong interest in D/MSM (expecting invitation by NASA for international missions)
- ▶ could be the "next big thing" after the ISS
- ▶ A&R has been identified as one strategic technology for European contribution !
- ▶ set of 3 General Studies for D/MSM launched in 2000
  - ◆ mission and systems, power / life support, A&R (AROMA)
  - ◆ see paper 1.2-4

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## Robotic Surface Exploration in Solar System (3)

- Mercury surface science
  - new ESA Science Cornerstone mission: BepiColombo
  - launch planned in 2009
  - will have a Lander funded by ESA (deviation from earlier science missions !!!)
  - A&R needed for lander science payload support: paper 1.2-5
  - several A&R technology development activities will be initiated
    - ◆ see presentation P. Putz on ESA R&D, paper 1.3-1
- surface / atmospheric science on other planets, moons
  - Mars, Venus, Europa still longer-term goals for ESA
  - also needed there: flying robots (aerobots)
    - ◆ national research has started: see demo
    - ◆ first ESA technology development activity planned, see presentation P. Putz on ESA R&D, paper 1.3-1

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## Non-Robotic Automation: Progress Report

- Successful missions since ASTRA 98:
  - Telescience Support Unit (TSU) for FluidPac (see ASTRA 98)
    - ◆ flew successfully on Foton 12 (9/99)
    - ◆ first real flight use of telescience
    - ◆ TSU performance exceeded expectations
    - ◆ not just for telescience, but as an interactive monitoring and debugging tool !
    - ◆ essentially rescued the FluidPac experiments ...
  - JET experiment on MASER-8 (see ASTRA 98)
    - ◆ successful sounding rocket mission in 1999
    - ◆ telescience ground interface for distributed scientific users successfully demonstrated
- MFC (Microgravity Facilities for Columbus): MSL, FSL, BioLab, EPM
  - ◆ in PDR / CDR stages of development
  - ◆ A&R contributions to embedded automation, more effective ground interaction
  - ◆ BioLab even has an internal manipulator

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### Non-Robotic Automation: Outlook

#### ● TSU-2

- upgraded version of TSU under development
- for an extended set of science facilities (FluidPac +) on Foton-M1 in 2002

#### ● MFC

- new Materials Science Lab (MSL-EML) for Columbus
  - ◆ joint ESA / DLR development
  - ◆ accelerated Phase A/B initiated in 2000
  - ◆ with enhanced automation technology

#### ● POST (Payload Operation Support Toolkit)

- based on POST 1 (TRP): s/w technologies for embedded experiment controllers
- POST 2 now proposed as core of Facility Responsible Center (FRC) for European Drawer Rack (EDR)
- see presentation P.Putz on ESA R&D, paper 1.3-1

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### Summary

- large space robot systems for ISS servicing
  - ◆ MSS and ERA are getting close to flight
  - ◆ exciting new uses have been identified (XEUS assembly)
- robotic payload tending on ISS
  - ◆ more frustrations (JERICO, EuTEF), more attempts (EUROPA, ExtRoTEF) ...
- free-flying robotics
  - ◆ we could see a revival (satellite retrieval, GEO maintenance)
- Mars robotics
  - ◆ Mars Express: Europe is catching up after US failures
  - ◆ still lack of ESA flight opportunities (esp. for rovers !), many bilateral cooperations
  - ◆ new major long-term perspective: robotics to support human missions !
- planet of the year: Mercury
  - ◆ new ESA science cornerstone mission with substantial need for surface A&R
  - ◆ ESA now funds also Lander !

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