

## The ESA R&D Programme in Space Automation & Robotics (2000 - 2002)

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### ESA Technology R&D Planning

- **Overall Framework**
  - Dossier 0, Technology Master Plan
- **ESA-internal activity proposals**
  - D/TOS proposals
    - about 1000 proposals submitted 4/99 (TRP and GSTP)
    - TRP proposals prioritised by a D/TOS “Technology R&D Working Group” 6/99
  - Other ESA internal proposals
    - by D/IMT and “User Directorates” (incl. D/MSM and D/SCI)
- **External activity proposals**
  - solicited from industry and national agencies
    - almost 1000 proposals received by fall 1999
- **Final TRD Workplan 2000 - 2002**
  - “project support” TRP part approved: ESA/IPC(2000)3
  - GSTP3 Workplan approved: ESA/IPC(2000)4, first subscriptions are in
  - “innovative” TRP (50 % of TRP budget ?): planning currently ongoing

## European Space Technology R&D Strategy

- **European Space Technology Requirements Document (“Dossier 0”)**
  - define objectives and priorities for space TRD in Europe
    - coherent roadmap of technology development needs and trends
    - for Europe’s public and industry-led space programmes
  - stakeholders:
    - ESA Programme Directorates, national space agencies, industry (EUROSPACE !), relevant DGs of the EC, academia
- **⇒ European Space Technology Master Plan (ESTMP)**
  - platform for harmonisation of TRD planning (on input from Dossier 0)
    - partnership ESA / national agencies / EC / industry
- **⇒ ⇒ Technology Master Plans**
  - ESA TMP
  - national agencies TMPs (ASI, CNES, DLR, ...)
- **⇒ ⇒ ⇒ Individual ESA R&D Programme Workplans**
  - TRP, GSTP, etc.

## Technology Requ. Document (Dossier 0)

- **Requirements for A&R**
  - Science and Exploration
    - Solar System Exploration
      - unmanned Mars missions (Mars Express and joint missions with NASA)
      - Mercury landing mission and possible sample return
      - others: Venus Sample Return
    - Astrophysics
      - High-energy missions: XEUS assembly / growth (TBC)
  - Manned Spaceflight and Microgravity
    - ISS Exploitation
      - evolution of ISS robotics systems (ERA, EuTEF, PAT, FFMOs)
    - Human Mars Exploration
      - A&R as one of 4 top strategic domains for Europe
    - Microgravity
      - still absent in current draft !

## Technology R&D at ESA: Main Programmes

- **General Studies Programme (GSP):**
  - mandatory ESA programme (funded from General Budget)
  - first studies into novel application domains, scenarios, systems
- **Technology Research Programme (TRP):**
  - mandatory ESA programme (funded from General Budget)
  - pre-development and more basic research (emphasis on innovation)
- **General Support Technology Programme (GSTP):**
  - optional ESA programme (member states fund “à la carte”)
  - component R&D, to produce mature building blocks for use in projects
- **Technology Flight Opportunities (TFO)**
  - formerly: (Flight) Technology Demonstration Programme (TDP)
  - mandatory ESA programme (funded from General Budget)
  - afford early in-flight experience of technology prototypes (covers launch and operations cost, not experiment development)

## Technology R&D for Space Robotics: Topics

- **System Technologies**
  - system and operational concepts
  - design and development methodologies
  - simulation, calibration
- **Subsystem Technologies (h/w and s/w)**
  - Support Equipment
    - testbeds, simulators, training equipment
  - Ground Segment
    - programming + verification, calibration
    - monitoring + commanding
    - telemanipulation / telepresence / telescience
  - Space Segment
    - mobility s/s (arm relocatability, guided mobility, rover locomotion, non-surface mobility)
    - manipulation s/s (kinematics, structures, actuators, proprioceptive sensors, harness)
    - EE and sensor instrumentation (grippers, hands, tools, payload i/f, exteroc. sensors)
    - control s/s (flyable h/w, algorithms, sensor based control, HCI)

## Past / Current R&D Activities at ASTRA 2000

- JERICO Evaluation Testbed
  - GSTP JET (paper 3.4-1, demo)
- ESA contributions to EUROPA
  - GSTP (paper 1.1-2, 3.4-2)
- Nanokhod micro rover system incl. end-to-end control
  - TRP MicroROSA, PSPE, RTPE (paper 3.7-1, exhibit, demo)
- Wheeled micro rover
  - TRP MIDD (demo)
- Radar sensor for rover piloting and subsurface science
  - TRP GINGER (paper 3.5a-1)
- Robotic deep drill system for Mars exobiology
  - GSTP MicroROSA 2 (paper 3.5a-4)
- Micro robot systems
  - TRP MRCC (paper 3.1-4, paper 3.2-3, exhibit)
- A&R for Human Mars Exploration
  - GS AROMA (paper 1.2-4)

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## R&D Activities for A&R (2000 - 2002)

Id. #	Init.	Application	IP	SME ?	GSP 00	TRP 00	TRP 01	TRP 02	GSTP00	GSTP01	GSTP02	D/MSM
<b>Generic Space Robot Technologies</b>												
MMA-601	MMA	Space A&R Controller Capability Extension	DN/C	n			400					
A07.MMH-014	IND	Robot Task Planner	C	y						300		
<b>Space Station Servicing</b>												
MMA-604	MMA	Robotic Ass'y of Large Space Structures	C	n		400						
A07.MMA-605	MMA	Control Stations for new Space A&R Applications	DN/C	y						600		
A07.MMH-013	IND	Telemanip. + Teleop. For Extra Vehicular Robotics	C	n						900		
A07.GB-I-001	IND	SPEAR Upgrading (for EUROPA)	DN/C	n					350			
MMA-622	MMA	MP "Dextrous Robot Syst. For ISS Ext. P/L Tending"	C	n		2000						2400
A07.MMA-001a	MMA	Lightweight Robot Structure	C	y						850		
A07.MMA-001b	MMA	End Effector for External P/L Tending	C	y						750		
A07.MMA-001c	MMA	Launch Retention + Latching S/S	C	y						600		
A07.MMA-001d	MMA	Ground Support Equipment	C	y						250		
<b>(micro-g) Science Facility Automation</b>												
A07.MMA-606	MMA	P/L Operations Support Toolkit (POST 2)	C	y					800			
<b>Robotic Satellite Servicing</b>												
N21	MMA	Robotic GEO Restorer (ROGER)	C		400							
<b>Planetary Exploration</b>												
S56	MSM	A&R for Human Mars Exploration (AROMA)	C		200							
MMA-607 / SO-AR-02	MMA	Planetary Aerobots	C	y			200					
SO-AR-01	SCI	Planetary Micro Probes	C				500					
BC-AR-03	SCI	Mercury Robotic Payload	DN/C				700					
BC-AR-06	SCI	Micro Mechanisms / Micro Cameras for Planet. Appl.	C				300					
A17.GB-I-002	IND	Guided Mole Development Demonstration	C	n						350		
Total TOS-MMA			13250		600	2400	2100	0	1150	4600	0	2400

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## **A&R Activities (1): Generic Technologies**

- **Space A&R Controller Capabilities Extension**
  - TRP MMA-601, 400 k, start 2001
  - DN(C) with TecnoSpazio (I) + DLR (D) + DASA (D) + Krypton (B)
  - extend capabilities of CESAR controller to proximity motion control, embedded on-line calibration, more advanced force and gripping control
- **Robot Task Planner**
  - GSTP A07.MM-I-014, 300 k, start 2001
  - C
  - Develop automatic planning and scheduling system for robot tasks given time and resource constraints. Integrate in ESTEC Testbed.

## **A&R Activities (2): Space Station Servicing**

- **Robotic Assembly of Large Space Structures**
  - TRP MMA-604, 400 k, C
  - ITT has been issued
  - Survey A&R-supported assembly techniques and the needed guiding, mating and latching mechanisms (in particular the robotic means available at the ISS)
  - Review proposed XEUS MSC assembly scenario at ISS against ISS robot systems capabilities and ISS operations rules
  - Design guiding, mating and latching mechanisms for MSC sectors, analyse compatibility with ISS-XEUS scenario
  - Breadboard critical A&R technologies and demonstrate feasibility.

## Space Station Servicing (cntd.)

- **Control Stations for New Space A&R Applications**
  - GSTP A07.MMA-605, 600 k, start 2001
  - DN(C) Trasys (B), SAS (B)
  - Develop instantiation of robot ground control station for new applications (e.g. PAT-class of ISS internal space robots). Develop “light” version for crew laptop implementation
- **Telemanipulation + Teleoperation for Extra Vehicular Robotics**
  - GSTP A07.MM-I-013, 900 k, start 2001, C
  - Add a telemanipulation environment to the existing ESTEC robot ground control system, especially for contingency operations.
- **SPEAR Upgrading**
  - GSTP A07.GB-I-001, 350 k, start 2000
  - DN(C) Tecnospazio (I) + DASA (D)
  - Upgrade the existing servo + power electronics assembly for longer lifetime missions with higher safety criticality (EUROPA).

## Space Station Servicing (cntd.)

- **Dextrous Robot System for ISS External P/L Tending**
  - Mini Project with several sub-activities
  - “main part”: TRP MMA-622, 2000 k + 2400 k D/MSM, start 2000, C
  - requirements analysis and system engineering; development of highly integrated lightweight robot joints; integration and qualification of sub-activity developments
- **Lightweight Robot Structure**
  - GSTP A07.MMA-001a, 850 k, start 2001, C
- **End Effector for External P/L Tending**
  - GSTP A07.MMA-001b, 750 k, start 2001, C
- **Launch Retention + Latching S/S**
  - GSTP A07.MMA-001c, 600 k, start 2001, C
- **Ground Support Equipment**
  - GSTP A07.MMA-001d, 250 k, start 2001, C



## **A&R Activities (3): Micro-g Facility Automation**

- **Payload Operations Support Toolkit (POST 2)**
  - GSTP A07.MMA-606, 800 k, start 2000
  - C
  - develop embedded controller for drawer level of ISS multi-user facilities (EDR, EuTEF), integrate and demonstrate in Facility Responsible Center at ESTEC

## **A&R Activities (4): Robotic Satellite Servicing**

- **RObotic GEostationary orbit Restorer (ROGER)**
  - GSP N21, 400 k, start 2000
  - C
  - Produce a statistical model of the expected future GEO utilisation, estimate risk from overcrowding and debris
  - define a concept for a robotic service vehicle to maintain and safeguard the public usability of the GEO orbit : services and usage, benefits and beneficiaries
  - establish design and development plans for a low cost in-orbit demonstrator and a fully operational system
  - produce promotional material for this new concept

## **A&R Activities (5): Planetary Exploration**

- **Autom. + Robotics for human Mars exploration (AROMA)**
  - GSP S56, 200 k, C
  - activity is running (Kayser-Threde (D) + subs.)
  - based on mission scenarios and top-level requirements from systems study (S51), establish and refine requirements + constraints for A&R for human Mars exploration
  - establish inventory of innovative A&R technologies
  - identify, trade-off and select reference A&R elements
  - perform system definition and preliminary design
  - identify critical technologies and propose a development plan

## **Planetary Exploration (cntd.)**

- **Planetary Aerobots**
  - TRP MMA-607 (SO-AR-02), 200 k, start 2001, C
  - first study of application scenarios, requirements, design approaches, critical technologies for aerobots (“flying robots”, e.g. balloons / airhips / blimps / autogyros / etc.)
- **Planetary Micro Probes**
  - TRP SO-AR-01, 500 k, start 2001, C
  - Develop a micro robotic probe (1 - 5 kg) for the in-situ exploration of planetary atmospheres and surfaces (most notably Mars, Europa).
  - Assess necessary scientific measurements and derived engineering requirements.
  - Establish a design concept, develop a breadboard model and test it in order to validate the concept.



## Planetary Exploration (cntd.):

- **Mercury Robotic Payload**
  - TRP BC-AR-03, 700 k, start 2001
  - DN/C von Hoerner & Sulger (D) with subs.
  - implement necessary modifications to the Nanokhod micro rover design and its p/l i/fs for Mercury surface operations
  - design, build and test a flight representative model of an end-to-end Nanokhod control system for the Mercury mission
  - produce an upgraded engineering model of the rover, test and demonstrate at ESTEC planetary robotics testbed
- **Micro Mechanisms and Adaptations of Micro Cameras to Planetary Applications**
  - TRP BC-AR-06, 300 k, start 2001, C
  - Develop and breadboard a miniaturised system for a Mercury lander to perform imaging for scientific purposes and to support control of the micro rover (terrain mapping, localisation).

## Problem: GSTP 3 Subscription Level

- For the proposed GSTP-3 activities, so far only CH has subscribed !
- If an activity is not subscribed, it will not be performed
- Since the initiation process for an activity takes at least 6 months, also 2001 / 2002 activities must be subscribed now !!
- But: every member state can subscribe every activity at any time (to any level, even > 100 %)
- **⇒ If you are interested in a proposed GSTP-3 activity, do lobby with your delegation to subscribe it !!**

## Outlook: Innovative TRP

- **Framework:**
  - overall budget: 25 M EUR over 2001 - 2003
  - guidelines currently established by ESA-internal “Innovation Task Force”
- **Characteristics of Innovative TRP activities:**
  - anticipating / supporting / enabling future missions / services
  - breakthrough in mission / service performance
  - but: no more than 10 years of development time
  - strategic for Europe and its industrial competitiveness
  - exploiting synergy with “terrestrial developments”
- **Current topics with relevance for A&R:**
  - dramatic miniaturisation (1/10 mass, power)
  - intelligent advanced operation modes (telepresence, autonomy)
  - innovative utilisation of the ISS
  - “clean orbits”
  - micro / nano system technologies for swarms

## AGAR (Advisory Group for A&R)

- Advisory Group to ESA IPC, to help establish a harmonised European work programme for space A&R
  - coordinate interests in applications, technology R&D
- Members:
  - ESA: C. Stavrinidis (TOS-M, chair), P. Putz (TOS-MMA, secretary)
  - Austria: ??
  - Belgium: J. Nijskens (OSTC), H. Van Brussel (KUL), F. Vandamme (BIKIT)
  - Canada: J.-C. Piedboeuf (CSA)
  - Finland: V. Kelhä (VTT Automation)
  - France: M. Maurette (CNES)
  - Germany: G. Gölz (DLR Bonn), G. Hirzinger (DLR Oberpfaffenhofen)
  - Italy: S. Di Pippo (ASI Rome), R. Mugnuolo (ASI Matera)
  - Netherlands: D. De Hoop (NIVR), C. Heemskerk (Fokker Space)
  - Portugal: ??
  - Spain: ??
  - Switzerland: R. Siegwart (EPFL), H.-M. Braun (RST AG)
  - UK: G. Pegman (UK Robotics Ltd.)

## Summary

- **ESA approach to TRD planning has been presented**
  - general and specifically for A&R
- **R&D Workplan 2000 - 2002 is established (TRP, GSTP 3)**
- **for A&R:**
  - 2 General Studies, total 600 kEUR
  - 7 TRP activities, total 4500 kEUR
  - 10 GSTP3 activities, total 5750 kEUR
  - co-funding by D/MSM: 2400 kEUR
  - overall: 19 activities, grand total 13250 kEUR
- **plus: “innovative TRP”**
  - “planned innovation” activities plus Announcements of Opportunity
  - total for A&R expected 2000 - 3000 kEUR
- **critical:**
  - D/MSM decision on Columbus external robot system (Mini Project !)
  - disappointing subscription level of GSTP 3 activities !!