

esa SP-297
December 1989

Second European In-Orbit Operations Technology Symposium

Proceedings of a Symposium
held in Toulouse, France,
12–14 September 1989

Sponsored by
European Space Agency
Centre National d'Etudes Spatiales (CNES)

Symposium Co-Chairmen
I. Braga (ESA) & J-J. Runavot (CNES)

Symposium Editor
E.J. Rolfe, ESA Publications Division



europaean space agency / agence spatiale européenne
8–10 rue Mario Nikis, 75738 Paris Cedex 15, France

RN 2087
(297)

Contents

Foreword	ix
----------	----

Session J1
Opening Session
Chairman: I. Braga

Opening address <i>M. Le Fèvre, Director of ESTEC</i>	xiii
Opening address <i>J.J. Sussel, Director of CNES Toulouse</i>	xv

Session J2
International Overview
Chairman: J.-J. Runavot

Columbus Laboratories Servicing Concepts <i>J.-J. Dordain</i>	xix
Toward the development of Cosmo-Lab <i>Y. Umetani</i>	xxi
Report on an oral presentation by N.N. Rukavishnikov <i>I. Braga</i>	xxvii
A proposed change to the NASA strategy for servicing space assets <i>G.M. Levin</i>	xxvix

Session A1
Space Station Operations
Chairman: R. Moe

On-orbit operations of the Space Station Freedom Attached Payload Accommodation Equipment (APAE) <i>J. Folse Lane & J. Stivaletti</i>	3
Operations considerations in Space Station Freedom assembly <i>S.C. Doering & W.G. Bastedo Jr.</i>	7
Robotics program at the NASA Goddard Space Flight Center <i>S. Ollendorf</i>	13

Session A2
Columbus Operations
 Chairman: U. Kirchhoff

- Columbus onboard Failure Detection, Isolation and Recovery (FDIR) concept 25
A. Kellner, R. Küke & J. Sved
- Servicing test facility: a hardware simulator for telerobotic in-orbit servicing 31
B.E. Schäfer
- Distributed mission planning technology for Columbus 39
G. Ohlendorf, A. Kellner & N. Schielow

Session A3
In-Orbit Serviceability
 Chairman: G.M. Levin

- Advanced robotics for in-orbit servicing 47
M. Oda
- In-orbit operations research and development programme of the Toulouse Space Centre 51
J-J. Runavot
- The Spider robotic system 57
S. Di Pippo, P.G. Magnani, W. Prendin & A. Terribile

Session A4
Servicing Interfaces
 Chairman: R.H. Bentall

- Development of cost-effective standards for Earth observation spacecraft 65
A.M. Federoff & N.I. Marzwell
- Flight support system servicing aid tool 73
R. Davis
- Hierarchy of on-orbit servicing interfaces 77
R.V. Moe

Session A5
EVA/IVA Perspective
 Chairman: A. Accensi

- Evolution of EVA capabilities for Space Station construction and maintenance: Soviet and American experience 85
C.D. Kramer

The European EVA suit: an optimised tool for Hermes/MTFF in-orbit operations <i>L. Simionesco, J.R. Chevallier, A.I. Skoog & N. Herber</i>	93
---	----

Perspective features of internal automation and robotics for supporting the Columbus Attached Laboratory payload operations <i>M. Cardano, M.S. Lavitola, I. Barraco & M. Toussaint</i>	99
--	----

Session A6
Robots : A Tool for the Astronauts
Chairman: H. Tolle

Telerobotic application to EVA <i>D.E. Anderson</i>	115
HERA & EVA cooperation scenarios <i>F. Didot & W. Luetngen</i>	123
Robot-based equipment manipulation and transportation for the Columbus Free-Flying Laboratory <i>W. De Peuter, P. Putz & G. Colombina</i>	129

Session A7
Teleoperation: A New Discipline
Chairman: E.B. Davies

The Hermes Robot Arm teleoperation and control concept <i>G. Andre & P. Schoonejans</i>	137
Telerobotic architecture for an on-orbit servicer <i>N.I. Marzwell</i>	151

Session A8
Teleoperation Test-Beds
Chairman: H.F.A. Roefs

HERA teleoperation test facility <i>V. Bourdon-Henry</i>	161
A flexible teleoperation test bed for human factors experimentation <i>J.L. Evans & I.G.D. Strachan</i>	167
Teleoperation of a force-controlled robot manipulator without force feedback to a human operator <i>M. Uchiyama & K. Kitagaki</i>	173

Session A9
Technology Challenges
 Chairman: I. Braga

- Experiences with, and error handling in, a knowledge base assisted system for payload experiment automation 183
G. Kegel & H. Tolle
- The Bi-Arm Servicer, a multi-mission concept and a technological model for space robotics 191
G. Andre, G. Berger & A. Elfving

Session B1
Rendezvous
 Chairman: W. Fehse

- Hermes rendezvous and navigation system 207
M. Frezet, P. Riant, M. Janvier & M. Caldichoury
- On-board expert system for manned rendezvous operation assistance 219
A. de Saint-Vincent & Ph. Marchal
- GPS navigational performance in space rendezvous operations 227
M.A. Martinez Olagüe, M. Perez Cortes & R. Lucas Rodriguez

Session B2
Docking
 Chairman: P. Marchal

- DDTF improvements for more accurate space docking simulation 239
D. Grimbart, P. Noirault, P. Marchal & L. Petitjean
- Investigations on docking and berthing dynamics 245
Th. Blais, Ch. Pauvert, W. Fehse & A. Tobias
- Docking berthing systems: functions and simulation 259
A. Tobias, F. Venditti & N. Cable

Session B3
Simulators A
 Chairman: P. Bernhard

- Ground-based simulations of in-orbit operations 273
T.E. Berg & M. Villaboe
- Robotic simulation support to systems development 281
R.M. Daintree & G.K. Speed

- Equivalent flexibility modelling: a novel approach for recursive simulation of flexible space-manipulator dynamics 289
P.Th.L.M. van Woerkom

Session B4
Simulators B
 Chairman: K. Reinel

- Simulation and ground-based testing of ORU handling with a bi-arm robot 299
H. Bruhm
- ROSED: Robotic Servicing Demonstrator 309
M. Van Winnendael, P. Gallet & P. Felix del Cueto
- The real-time Hermes Robot Arm simulator : HSF-P 315
J.J.M. Prins, P. Dieleman and H. de Jong

Session B5
ORU Techniques
 Chairman: F. Cepollina

- Orbital Replacement Units (ORUs) design considerations 325
E. Falkenhayn
- Technology requirements for on-orbit servicing of spacecraft 329
O.C. Ledford & N. Ely

Session B6
Servicing Techniques
 Chairman: A. Loria

- Satellite Servicer System Flight Demonstration Program 337
J.S. Moore
- Interconnecting devices conceived for in-orbit operations 341
P. Sequi & J. Laffin
- Development of a fully automated fluid resupply interface system 351
J.M. Cardin, W.C. Boyd & M.S. Falls

Session B7
Robot Systems
 Chairman: M. Maurette

- NASREM: a functional architecture for control of the flight telerobotic servicer 361
R. Lumia

Collision detection using linear programming <i>R. Gallerini & A. Sciomachen</i>	367
The Hermes Robot Arm - system description <i>R.J. Hamann & R.H. Bentall</i>	373

Session B8
Robot Components
 Chairman: U. Kirchhoff

NASA/GSFC split-rail parallel gripper <i>J.M. Vranish & M. Sharifi</i>	383
A three-fingered, multi-joint gripper as a working tool for experimental use <i>W. Paetsch & M. Kaneko</i>	389
High-performance processing system for embedded control applications in space <i>A. Elfving & A.T. Sund</i>	393

Session B9
Dynamic Controls
 Chairman: J.-J. Runavot

Dynamic modelling and control of a flexible arm holding a non-rigid payload <i>P. Carton, J.P. Chrétien & M. Maurette</i>	405
Dynamics and control of free-flying inspection and maintenance vehicle with manipulators <i>J. Marczyk & A. Bellazzi</i>	413
Supervisory controlled telemanipulation and vision systems for inspection and maintenance operations <i>W. Prendin, D. Maddalena, A. Terribile & G.S. Labini</i>	429
Late Paper	
Flexible test bed for space telepresence and telemanipulation research <i>M. Andrenucci, M. Bergamasco, P. Dario & G. Sandini</i>	439
List of Participants	447