

*The 3<sup>rd</sup> International Symposium on*

# **Formation Flying, Missions and Technologies**

23–25 April 2008  
ESA-ESTEC  
Noordwijk, The Netherlands

*Programme Committee*

F. Ankersen (Chair), ESA  
J. Leitner (Co-Chair), GSFC  
A. Ng (Co-Chair), CSA  
M. Bavdaz, ESA  
M. Cosmo, ASI  
R. Crowther, RAL  
S. D'Amico, DLR  
I. Gibson, BNSC  
J. Gonzalez, ESA  
F. Hadaegh, JPL  
B. Jakobsson, SNSB  
Y. King, USAF  
M. Landgraf, ESA  
T. Lovell, USAF  
V. Lukyaschenko, TsUP  
L. Ming, CNSA  
O. Mitsushige, JAXA  
P. Pelipenko, CNES  
S. Persson, SNSB  
V. Saulskiy, TsUP  
D. Seguela, CNES  
S. Shin-Ichiro, JAXA  
Z. Sodnik, ESA  
F. Svelto, ASI  
F. Teston, ESA  
Z. Yunhua, CNSA  
R. Zamanabadi, DNSC

*Local Organising Committee*

F. Ankersen, L. Maresi

*Publication*

Proceedings of the 3<sup>rd</sup> International Symposium on Formation Flying,  
Missions and Technologies  
ESA/ESTEC, Noordwijk, The Netherlands (ESA SP-654, June 2008)

*Edited by*

K. Fletcher  
ESA Communication Production Office

*Published and distributed by*

ESA Communication Production Office  
ESTEC, Noordwijk, The Netherlands

*Price*

EUR 60

*ISBN*

978-92-9221-218-6

*ISSN*

1609-042X

*Copyright*

© 2008 European Space Agency

# CONTENTS

## New Mission Concepts

*Chairs: Simone D'Amico, Alexander Cropp*

Fresnel Formation Flying: High Resolution Imager for Optical Astrophysics  
*Hinglais, E.; Duchon, P.; Koechlin, L.; Serre, D.; Deba, P.*

An Innovative Spaceborne P-Band SAR Mission Based on Small Satellites and Formation Flying Technologies  
*Fasano, G.; Alberti, G.; D'Errico, M.; Cesare, S.; Sechi, G.; Mazzini, L.; Pavia, P.; Torre, A.; Esposti, M.L.; Zin, A.; Matticari, G.; Bavaro, M.; Dionisio, C.; Cosmo, M.; Formaro, R.; Rioli, Q.*

PROBA-3: A Formation Flying Demonstration Mission on the Verge to be Realised  
*Sjöberg, F.; Karlsson, A.; Jakobsson, B.*

The FFIORD Experiment: CNES' RF Metrology Validation and Formation Flying Demonstration on PRISMA  
*Harr, J.; Delpech, M.; Grelier, T.; Seguela, D.; Persson, S.*

Novel EMMA Arrangement for DARWIN Mission  
*Sghedoni, M.; Krawczyk, R.; Pirson, L.; Ruilier, C.*

Formation Flying Aspects of Different Instrument Concepts for DARWIN/TPF-I  
*Wallner, O.; Ergenzinger, K.; Flatscher, R.; Johann, U.*

Nonlinear Performance Analysis of DARWIN with respect to Formation Flying Fine Control Loops  
*Ergenzinger, K.; Wallner, O.; Villien, A.*

## **Technologies and Design of Distributed Sensors Needing Formation Flying**

*Chairs: Luca Maresi, Zoran Sodnik*

High Accuracy Absolute Long Distance Metrology using Femto-Second Lasers: Optical Frequency Combs and Spectral Interference Techniques  
*Holzwarth, R.; Eikema, K.; Steinmetz, T., Hänsch, T. W.; Klein, V.; Gill, P.; Barwood, G.; Margolis, H.*

High Accuracy Absolute Long Distance Metrology using Femto-Second Lasers: Optical Heterodyning, Electrical Heterodyning and Applying FSL-Systems  
*Verlaan, A.L.; Cabral, A.; Abreu, M., Witte, S. Flatscher, R.*

Design and Performance Testing of the 5 Degree of Freedom Formation Flying Sensor  
*Verlaan, A.L., Cuyllé, S.H.*

An Integrated Formation Optical Communication and Estimation System for Precision Collaborative Missions  
*Scharf, D.P.; Hadaegh, F.Y.; Kuhnert, A.C.; Kovalik, J.M.; Açikmeşe, B.*

A Generic Radio-Frequency Subsystem for High-Altitude Formation-Flying Missions  
*Thevenet, J.-B.; Mehlen, C.; Peyrotte, C.; Grelier, T.; Lestarquit, L.; Garcia, A.; Gerner, J.-L.*

ULLIS - A Combined Optical Metrology Sensor with Minimum Accommodations Constraints  
*Napierala, B.; Leyre, X.; Sghedoni, M.; Rossi, E.*

A Lateral Sensor for SimbolX Derived from Hydra Star Tracker  
*Blarre, L.; Chalte, C.; Pezant, C.; Le Duigou, JM.; Martinez, PE.*

## **Platform Technologies (propulsion, power supply, attitude, ranging, etc.)**

*Chairs: Alfred Ng, Li Ming*

Improvements of the ONERA MicroNewton Thrust Balance  
*Bonnet, J.; Rocca, S.; Packan, D.*

Laser Induced Fluorescence in a Cesium Plume: Application to Micronewton Thrusters  
*Packan, D.; Bonnet, J.; Elias, P. Q.; Rocca, S.*

Miniaturised Differential Gridded Ion Thruster System  
*Corbett, M.H., Collingwood, C.M., Jameson, P.*

Design and Control of Formation Flying Systems for Remote Sensing Missions with Electric Propulsion  
*Cornara, S.; Fernández, V.; Peñín, L.F.; Bastante, J.C.*

A Novel, Rugged and Robust Longitudinal Range Finding Method for Formation Flying Missions  
*McDonald, G.; Orchard, D.; Lewin, A.*

An Alternative Metrology Concept: Ray Trace Ranging  
*Hagenfeldt, N.M.; Karlsson, A.; Sequeira, J.*

Data Handling Solutions Based on RF Metrology Services  
*Andreis, O.; Dellandrea, B.; Mehlen, C.; Alison, B.; Cazaux, J.M.*

## **Orbit Design and Trajectories**

*Chairs: Eberhard Gill, Mario Cosmo*

Magic (Special) Inclinations for Formation Flying  
*Izzo, D.; Sabatini, M.*

Solar Radiation Pressure Effects on Very High-Eccentric Formation Flying  
*Fontdecaba Baig, J.; Métris, G.; Gamet, P.; Exertier, P.*

Formation Flight Stability in a Gravitational Field  
*Sneeuw, N.; Sharifi, M.; Schaub, H.*

Configuration Angle Determination and Configuration Optimal Design of Distributed SAR Satellite System  
*Zhang, J.X.; Wu, Y.H., Cao, X.B.; Lan, S.C; Wang, J.H.*

## **Guidance, Navigation and Control Systems, part 1**

*Chairs: Jesse Leitner, Thomas Chabot*

DARWIN: A GNC Design for the EMMA Arrangement  
*Pirson, L.; Sghedoni, M.; Krawczyk, R.; Ankersen, F.*

GNC for the Darwin Mission  
*Villien, A.; Wallner, O.; Ergenzinger, K.*

FF Analysis and GNC Concept for a FF Mission in Highly Eccentric Orbit  
*Di Sotto, E.; Peñín, L.F.; Bastante, JC; Marcos, A.; Branco, J.*

Orbit Constellation Safety on the PRISMA In-Orbit Formation Flying Test Bed  
*Larsson, R.; Mueller, J.; Thomas, S.; Jakobsson, B.; Bodin, P.*

Design and Control of Relative Motion for Interferometric and Bistatic SAR  
*Sabatini, M.; Fasano, G.; Palmerini, G.; D'Errico, M.*

Relative Motion Control for Along-Track Formation Flight in Low Earth Orbit: Linear Synthesis with Non-Linear Actuators  
*Demourant, F.; Chrétien, J.-P.*

Pattern Transition in Spacecraft Formation Flying Via the Artificial Potential Field Method and Bifurcation Theory  
*Bennet, D.J.; McInnes, C.R.*

## **Guidance, Navigation and Control Systems, part 2**

*Chairs: Fred Hadaegh, Finn Ankersen*

Analysis of a Pulsed Cold Gas Option for the XEUS/XRO Mission

*Chabot, T.; Rando, N.*

Formation Flight Static Output Feedback Control: Evaluating the Need for Scheduling over an Eccentric Orbit

*Kron, A.; de Lafontaine, J.; Ulrich, S.*

Minimum-Fuel Deployment of Formation Flying Satellites - An Optimal Control Approach

*Epenoy, R.*

Electro Magnetic Formation Flight for LEO Satellites

*Sakai, S.; Kaneda, R.; Maeda, K.; Saitoh, T.; Saito, H.; Hashimoto, T.*

TanDEM-X Autonomous Formation Flying System

*Ardaens, J.S.; D'Amico, S.; Ulrich, D.; Fischer, D.*

New Approaches to Distributed Control of Satellite Formation Flying

*Massioni, P.; Keviczky, T.; Verhaegen, M.*

Two-Stage Optimal Manoeuvre Planning for Spacecraft Formation Flying Missions

*Burgon, R.; Roberts, P.C.E.; Ankersen, F.*

## **Guidance, Navigation and Control Systems, part 3**

*Chairs: Pierre Pelipenko, Björn Jakobsson*

The Guidance and Control Algorithms for the CANX-4&5 Formation Flying Demonstration Mission

*Eyer, J.; Damaren, C.; Zee, R.*

Relative Orbit Initialization Control for Formation Flying Spacecraft with Thrust Direction Maneuverability Constraints

*Wu, Y.H.; Cao, X.B.; Zheng, P.F.; Xing, Y.J.; Zhang, S.J.*

A Survey of Coupled Control for Spacecraft Formation Flying

*Wu, Y.H.; Cao, X.B.; Xing, Y.J.; Zheng, P.F.; Zhang, S.J.*

## **Operations, Mission Planning**

*Chairs: Dominique Seguela, Mitsushige Oda*

Reconfiguration Maneuver Experiments Using the SPHERES Testbed Onboard the ISS

*Aoude, G.S.; How, J.P.; Miller, D.W.*

Spacecraft Formation Reconfiguration with Collision Avoidance

*Schlanbusch, R.; Kristiansen, R.; Nicklasson, P.J.*

PROBA-3 Ground Segment and Operation Concept  
*Tarabini-Castellani, L.; Wishart, A.; Grocott, S.*

Orbit Determination & Relative Positioning Techniques for JC2Sat  
*De Ruiter, A.; Lee, J.; Ng, A.; Kim, Y.*

Differential Ionospheric Effects in GPS Based Navigation of Formation Flying Spacecraft  
*van Barneveld, P.W.L.; Montenbruck, O.; Visser, P.N.A.M.*

PROBA-3 Formation Flying Mission Analysis  
*Peters, T.V.; Tarabini-Castellani, L.; de Negueruela, C.; Llorente, S.; Jakobsson, B.*

Short Range Pose and Position Determination of Spacecraft using a  $\mu$ -Advanced Stellar Compass  
*Benn, M.; Jørgensen, J.L.*

Spacecraft Formation Control: Managing Line-of-Sight Drift Based on the Dynamics of Relative Motion  
*Luquette, R.J.; Sanner, R.M.*

Autonomous Rendezvous Experiments on the PRISMA In-Orbit Formation Flying Test Bed  
*Nilsson, F.; Bodin, P.; Chasset, C.; Jakobsson, B.; Larsson, R.; Noteborn, R.; Vinterhav, E.*

## **Design and Simulation Tools for Involved Fields**

*Chairs: Jesse Leitner, Thomas Alan Lovell*

PERSEE: A Nulling Breadboard Coupled with a Free Flying GNC Simulator  
*Le Duigou, J.M.; Cassaing, F.; Houairi, K.; Jacquinod, S.; Reess, J.M.; Hénault, F.; Sorrente, B.; Barillot, M.; Mourard, D.; Coudé du Foresto, V.; Ollivier, M.*

Ground Demonstration of Synchronized Formation Rotations for Precision, Multi-Spacecraft Interferometers  
*Scharf, D.P.; Hadaegh, F.Y.; Keim, J.A.; Lawson, P.R.*

A Piecewise Affine Hybrid Systems Approach to Fault Tolerant Satellite Formation Control  
*Grunnet, J.D.; Larsen, J.A.; Bak, T.; Wisniewski, R.*

Preliminary Design Optimization of A Microsatellite Formation Flying for Radar Interferometric Applications  
*Gaias, G.V.M.; Lavagna, M.R.*

Design and Analysis Capabilities of LODATO for Formation Flying Libration Point Missions  
*Sánchez, M.; Gómez, G.; Masdemont, J.J.; Peñín, L.F.*

Selected Afternoon Constellation Transient Plume Impingement Model Results  
*Woronowicz, M.*

Offline and Hardware-in-the-loop Validation of the GPS-Based Real-Time Navigation System for the PRISMA Formation Flying Mission  
*D'Amico, S.; De Florio, S.; Ardaens, J.S.; Yamamoto, T.*

Optimized Relative Motion for Spacecraft Formation  
*Altés Arlandis, B.; Cremaschi, F.; Schäff, S.; Erb, S.; Ortega, G.*

Ground Validation of Formation Flying Techniques and Technologies

*Borde, J.; Schirmann, T.; Barillot, P.; Villien, A.; Ergenzinger, K.; Barrena, V.; Lumb, D.*

## **Multiple Spacecraft Missions**

*Chairs: Yolanda King, Ian Gibson*

A Possible Dual-GRACE Mission with 90 Degree and 63 Degree Inclination Orbits

*Bender, P.I.; Wiese, D.N.; Nerem, R.S.*

Satellite-to-Satellite Laser Tracking for a Next Generation Gravimetric Mission

*Cesare, S.; Biondetti, G.; Mottini, S.; Parisch, M.; Sechi, G.; Canuto, E.; Pisani, M.; Aguirre, M.; Leone, B.; Massotti, L.; Silvestrin, P.*

LISA – A Mission to Detect and Observe Gravitational Waves

*Jennrich, O.; McNamara, P.; Bender, P.*

Analysis of Satellite Formations in the Context of Gravity Field Retrieval

*Encarnacao, J.; Ditmar, P.; Liu, X.*

## **Poster Session**

PROBA-3 Formation Flying System Perspectives

*Llorente, J.S.; Agenjo, A.; Bereczki, B.; Tarabini-Castellani, L.; Jacobsson, B.; Cropp, A.*

New Simulation Concepts Applied to Formation Flying Testbed Design

*Atori, R.; Baudoux, D.; Torette, D.; Goode, K.; Tarabini, L.; Franco, R.*

Delfi-TWIN: A Formation Flying Mission Concept

*Aas, C.; Leijtens, J.; de Milliano, M.; Gill, E.*

Orbits for LISA - Formation Flying without Orbit Maintenance

*Jennrich, O.*

GA-Based Optimization for Formation Flying Initialization

*Cao, X.B.; He, D.L.; Zhang, J.X.; Wu, Y.H.*

Research on the Model Predictive Control Approach for Satellite Formation Keeping

*Cao, X.B.; He, D.L.; Zhang, J.X.; Wu, Y.H.*

Evaluation and Comparison of Two Impulsive Control Theories for Satellite Formation Establishment

*Wang, J.H.; Zhang, J.X.; Wu, Y.H.; Cao, X.B.*

Carrier-Based Differential GPS Filtering Approaches for Precise Relative Positioning in Formation Flying with Highly Variable Inter-Satellite Distances

*Renga, A.; Grassi, M.; Intelisano, A.*



Radio-Frequency Based Relative Navigation for Formation Flying

*Kervendal, E.; Voirin, T.; Degeselle, J.; Villien, A.; Grelier, T.; Delpech, M.*

Formation Flying RF Ranging Subsystem for PRISMA: Navigation Algorithm Design and Implementation

*Barrena, V.; Suatoni, M.; Flores, C.; Thevenet, J.B.; Mehlen, C.*

Formation Control by Quantized Output Feedback

*Grøtli, E.I.; Gravdahl, J.T.*

PID+ Tracking in a Leader-Follower Spacecraft Formation

*Kristiansen, R.; Krogstad, T.R.; Nicklasson, P.J.; Gravdahl, J.T.*