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RTO EDUCATIONAL NOTES **EN-SCI-209**

Small Satellite Formations for Distributed Surveillance: System Design and Optimal Control Considerations

(Formations de petits satellites pour une surveillance distribuée: Considérations relatives à la conception de système et à l´optimisation de commandes)

The material in this publication was assembled to support a Lecture Series under the sponsorship of the Systems Concepts and Integration Panel (SCI) presented on 1-2 April 2009 at Stanford University, CA, USA; on 6-7 April 2009 in Würzburg, Germany, and on 8-9 April 2009 in Rome, Italy.

Published April 2009

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The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Small Satellite Formations for Distributed Surveillance: System Design and Optimal Control Considerations

(RTO-EN-SCI-209)

Executive Summary

In Earth observation, the innovation potential by employing a distributed network of satellites became obvious from the tandem solutions of two satellites, having been realized so far. From 2008 on, constellations of satellites will be placed in orbit in order to provide higher temporal resolution in observation data and to achieve higher availability. Especially in emergency, surveillance and military observation tasks, such robust capabilities for observation are important. In addition by using groups of satellites, objects can be viewed from different perspectives in order to enable 3-dimensional reconstruction of data, in particular a virtual instrument can be realized with long baselines and a related high resolution. In case of failures, even graceful degradation capabilities are related to formations of satellites. Currently modern miniaturization techniques enable in parallel realisation of satellites at continuously smaller masses, leading to decreased launch costs. Thus currently a paradigm shift in Earth observation from single large satellites to groups of smaller satellites is occurring.

This lecture series addresses crucial system design challenges in implementing satellite formations for telecommunication and surveillance, with emphasis on innovative techniques and their application potential.

Formations de petits satellites pour une surveillance distribuée: Considérations relatives à la conception de système et à l'optimisation des commandes

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Synthèse

Dans le domaine de l'observation terrestre, le potentiel d'innovation représenté par l'emploi d'un réseau distribué de satellites est devenu évident dès la réalisation, à ce jour, d'un tandem de deux satellites. A partir de 2008, des constellations de satellites seront placées en orbite pour obtenir une meilleure résolution temporelle des données d'observation et pour obtenir une plus grande disponibilité. Ces capacités robustes d'observation sont particulièrement importantes, pour les missions de surveillance et d'observation militaire en période de crise. De plus, en utilisant un groupe de satellites, les objets peuvent être vus selon différentes perspectives afin de rendre possible la reconstruction des données en 3D, en particulier un instrument virtuel peut être réalisé avec d'importantes bases de référence et une haute résolution associée. En cas de panne, c'est grâce aux formations de satellite que le potentiel de dégradation est facilement aplani. Les techniques de miniaturisation modernes actuelles permettent par ailleurs la réalisation de satellites de moins en moins lourds réduisant ainsi les coûts de lancement. Ainsi, concernant l'observation terrestre, on observe un changement de positionnement avec le glissement des gros satellites uniques vers des groupes de satellites plus petits.

Cette série de conférence traite des principaux défis de la conception de systèmes lors de la mise en œuvre de formations de satellites pour des missions de surveillance et de télécommunications, en mettant l'accent sur les techniques innovantes et leurs applications potentielles.

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