Advanced Maui Optical and Space Surveillance Technologies Conference
SEPTEMBER 11-14, 2018 - MAUI, HAWAI'I | A PROGRAM OF maui economic DEVELOPMENT BOARD

SHORT COURSE SCHEDULE – AMOS 2018

(Separate registration fee required for each course)

Tuesday 11 September

8:00 AM - 12:00 PM **TECHNICAL SHORT COURSES 1 – 4** *(run concurrently)*

1 Conjunction Assessment Risk Analysis

Presented by:
Francois Laporte and Monique Moury, CNES
Matt Hejduk and Lauri Newman, NASA CARA

The threat of on-orbit collisions has become an increasing concern to the spacefaring community, both as an increasing mission risk due to a more congested space environment and through wider community awareness of the problem. The operational practice of conjunction assessment in response to this risk has also become more commonplace, evolving from simply predicting close approaches between orbiting objects to sophisticated systems and processes for managing on-orbit collision risk. This short course taught by subject matter experts in the field, is designed to educate beginners to intermediate-level practitioners on the fundamentals of conjunction assessment. The three-part overview of Conjunction Assessment will cover the topics below, and aims at making participants conversant in the theoretical underpinnings and operational practices of conjunction assessment.

The first part is an extended background theory section that includes all the theoretical components which are needed in order to perform conjunction analysis and associated risk assessment. Topics include relevant astrodynamics basics, orbit determination methodologies, space situational awareness basic concepts, and satellite conjunction assessment theory.

The second part of the course contains a treatment of modern conjunction risk assessment practices. The presenters share their operational experience and lessons learned, including some historical collision and close approach prediction statistics. Topics in this section include using and interpreting satellite probabilities of collision, designing and evaluating collision risk mitigation maneuvers, and understanding and processing the various relevant conjunction assessment data products, including those provided by the 18th Space Control Squadron. The course describes the CA Middle Man role through two examples with their similarities and particularities:

- The American organization delivered by the NASA Conjunction Assessment Risk Analysis (CARA) team, and
- The French organization delivered by the CNES Conjunction Assessment and Evaluation Service: Alerts and Recommendations (CAESAR) team.

The third part contains a treatment of emerging technical and policy challenges for conjunction assessment activities. The space environment has been rapidly evolving, and is expected to continue to do so in the coming years. These changes include:

- Many companies are proposing very large constellations
- Cubesats are making space accessible to non-traditional space operators
- Regulation and best practices are evolving
- Efforts continue to define an architecture for a consolidated governmental or international Space Traffic Management (STM) entity
- The incipient deployment of the Air Force's Space Fence radar is expected to greatly increase the number of catalogued space objects

Participants will gain a better understanding of how conjunction assessment fits as part of the big picture of the space environment, its importance to routine space operations, and the interconnectivity of emerging technologies with CA.

8:00 AM - 12:00 PM TECHNICAL SHORT COURSES 1 - 4 (Cont.)

2 Space Debris Risk Assessment and Mitigation Analysis –Verification of compliance with requirements on space debris mitigation using ESA's DRAMA software

Presented by:
Tim Flohrer, Space Debris Analyst, SST Segment Co-Manager, ESA/ESOC Space Debris Office
Benjamin Bastida Virgili, Space Debris Engineer, ESA/ESOC Space Debris Office

For more than twenty years, the Inter-Agency Space Debris Coordination Committee (IADC), which is represented by space agencies from thirteen member states, has been coordinating space debris mitigation activities. IADC guidelines were the basis for space debris mitigation requirements that became applicable to space missions, e.g., conducted by NASA or ESA, but also found their way into national space law, for example in France. In order to verify that requirements are met, the agencies almost entirely rely on the use of qualified tools. In view of the increasing number of parties involved in launching and operating spacecraft, qualified tools establish the means to assess the mitigation-related aspects of the mission design in an early project phase and to compare them to results obtained for other missions and designs.

The objective of this course is to provide an elementary introduction to ESA's corresponding tools that are provided as a collection in the Debris Risk Assessment and Mitigation Analysis (DRAMA) tool suite. It will enable the participants to perform the required mitigation and risk analyses in order to verify the compliance of mission scenarios with space debris mitigation requirements.

DRAMA is available from ESA for users worldwide subject to a registration, and free of charge.

3 Operational Analytics: Demystifying Machine Learning

Presented by:
Joseph Coughlin, Senior Aerospace Systems Engineer, L3 Applied Defense Solutions
Rohit Mital, Chief Technology Officer, Stinger Ghaffarian Technologies

Operators and analysts are being overwhelmed with the amount of data available from both existing and new classes of sensors. The magnitude of the data becomes too great to analyze by conventional means. Machine Learning has often been proposed as a solution to the "big data" problem which will enable analysts to evaluate and determine courses of action based on the information. A lot of mystery and misinformation surrounds Machine Learning and its potential. This short course builds upon the course given last year (but is not a prerequisite) by reviewing a methodology to implement Operational Analytics and Predictive techniques and further delving into how to use Machine Learning to solve SSA problems of interest to AMOS participants.

This course presents a detailed overview of current technologies and software and hardware architectures for aspiring or current users to utilize Operational Analytics and Machine Learning in their exploitation of SSA data as well as discussing paths toward building future architectures. There are a number of advantages and pitfalls in using Machine Learning which will be discussed. The different approaches and applications of Machine Learning, such as supervised, unsupervised learning, clustering, and deep learning, will be presented with practical examples using SSA data. Where applicable, software snippets will be presented to help in understanding implementation. Although many of the cases presented deal with the exploitation of optical data, the techniques can be applied to other data types as well.

4 Introduction to theory and application of multi-objective optimization using Genetic Algorithm

Presented by:
Triet Tran, Senior Aerospace Consultant, Cornerstone Consulting LLC

Most real-world optimization problems are multi-dimensional in both the search space and the objective space. A familiar example is in the area of financial investment where the objectives are to minimize investment risk but at the same time maximize investment return in which the search space is the wide variety of investment instruments and the financial asset to be allocated to the specific investments. The same can be said about the domain of Space Situation Awareness (SSA). With limited tracking assets to track increasing number of Resident Space Objects (RSOs), the scheduling objectives could be to maximize the usage efficiency of all the tracking assets while achieving an acceptable level of orbital state accuracy for all RSOs for catalog maintenance.

These are complex optimization problems and cannot easily be solved using traditional methods. Genetic Algorithm has seen significant growth for the past 15 years with respect to multi-objective optimization. Genetic Algorithm is a modern heuristic search algorithm based on the concept of "survival of the fittest" borrowed from the theory of biological evolution.

It is fair to say that the Genetic Algorithm is most easily adaptable to solving multi-objective optimization problems. The key in applying GA is the engineering interpretation of the attributes that an individual within the population carries. Another appealing aspect of the Genetic Algorithm is the fact the individuals can be evaluated for their fitness independent of one another. This means that it is very natural to employ the parallel processing power of the Graphical Processing Unit (GPU) to improve the execution speed of GA.

This course will present the key concepts of genetic algorithm as applied to multi-objective optimization. The algorithm will be explained in details including the concepts of multi-dimensional search space and multi-dimensional objective space. Hands-on exercises will be used to provide the students with a feel for how the Genetic Algorithm works. Applications of the multi-objective optimization to the problem of resource allocation will be demonstrated live in class. The presenter will show how the problem of tracking resource utilization for SSA can be addressed with this modern optimization technique.

1:00 PM - 5:00 PM **TECHNICAL SHORT COURSES 5-7** *(run concurrently)*

5 Statistical Orbit Determination for Space Surveillance and Tracking

Presented by:
Moriba Jah, The University of Texas at Austin

There is a growing number of Resident Space Objects (RSOs) in Earth orbit given a new space race driven mostly by commercial actors. Space Traffic Management has become a critical topic with challenging problems to solve and no real or meaningful solutions in sight. Part of what is needed, is the ability to confidently and reliably detect, track, identify, and characterize RSOs. Space Surveillance and Tracking (SST) is one major pillar of Space Situational Awareness (SSA) recognized as such the world over. This short course will focus upon providing the student with an overall understanding of the various components of statistical orbit determination within the context of SST for SSA.

At the conclusion of this course, each student should be able to:

- Describe the basic history and purpose of statistical orbit determination
- Describe the effects and impacts of the space environment on space object motion
- Describe a model for the following observables: range, Doppler/range-rate, angles (e.g. az-el), and inertial measurements
- Understand how to propagate and simulate orbital trajectories under a variety of perturbations
- Estimate the trajectory of a Resident Space Object (RSO) from a variety of tracking and/or inertial measurement unit data
- Formulate an applied estimation solution to the Orbit Determination problem based on a variety of observables
- Understand how one can refine the trajectory solution by estimating for various model parameters and making appropriate corrections
- Understand and describe a variety of Orbit Determination strategies to successfully determine the cause of observed phenomenology in observable data

1:00 PM - 5:00 PM **TECHNICAL SHORT COURSES 5-8 (cont'd)**

6 Observing and Characterizing Space Debris
Presented by:
Thomas Schildknecht, Astronomisches Institut Universität Bern

The proliferation of space debris and the increased probability of collisions and interference raise concerns about the long-term sustainability of space activities, particularly in the Low-Earth orbit and geostationary orbit environments. During recent years governments, space agencies and civilian research organizations increased their efforts to build space object catalogues and to investigate the space debris population in different orbit regions. Understanding the nature and the sources of debris is a prerequisite to provide the scientific foundation for a sustainable use of near-Earth space.

This course will provide a general introduction to the space debris problem, give an overview on the current space debris research activities to detect and characterize space debris, followed by a presentation of the efforts to model the future space debris population and the international efforts to protect and remediate the space environment. Particular focus will be put on optical techniques to detect, track and characterize space objects including small-size debris. The techniques will be illustrated with examples from the long-standing observation programs of the Astronomical Institute of the University of Bern (AIUB).

7 Machine Learning for Space Situational Awareness
Presented by:
Kyle Pula, Research Scientist, CACI
Richard Linares, Assistant Professor, University of Minnesota
Roberto Furfaro, Associate Professor, Univ. of Arizona

Over the past decade, the field of machine learning has experienced incredible improvements in the applicability and accuracy of its techniques. These advances present huge opportunities for the SSA community as it faces ever increasing scope, sensing modalities, and data volumes. The short course will survey recent advances in machine learning and associated applications to SSA.

The first portion of the course will cover a broad overview of modern machine learning techniques with an emphasis on those areas that seem most directly relevant to SSA. The second portion of the course will examine a set of case studies of the techniques being applied to real SSA problems, including code examples in MATLAB (neural networks toolbox/statistics and machine learning toolbox) and Python.