COE CST Fourth Annual Technical Meeting

Center of Excellence for Commercial Space Transportation

Task 244: Autonomous Rendezvous & Docking for Space Debris Mitigation

Norman Fitz-Coy

October 29-30, 2014
Washington, DC

Agenda

- Team Members
- Task Description
- Schedule
- Goals
- Results
- Conclusions and Future Work

Team Members

- Principal Investigator
  - Norman Fitz-Coy
- Students
  - Tristan Newman (MS student)
  - Kathryn Cason (accepted job with MIE)
  - Takashi Hiramatsu (PhD in 2012 – NESTRA)
- Organizations
  - Collaborator: NASA ODPO (J.-C. Liou)
  - Matching provided by: Space Florida

Task Description (Original)

- Active debris removal is required
  - Interests in small satellites (e.g., CubeSats) especially by new space entrant leads to:
  - More spacecraft → more failure (debris)
  - Debris likely to be non-cooperative
- Objective
  - Develop strategies to minimize interactions during removal of non-cooperative debris
  - Develop strategies for safe proximity operations / collision avoidance during removal

Task Description (Revised)

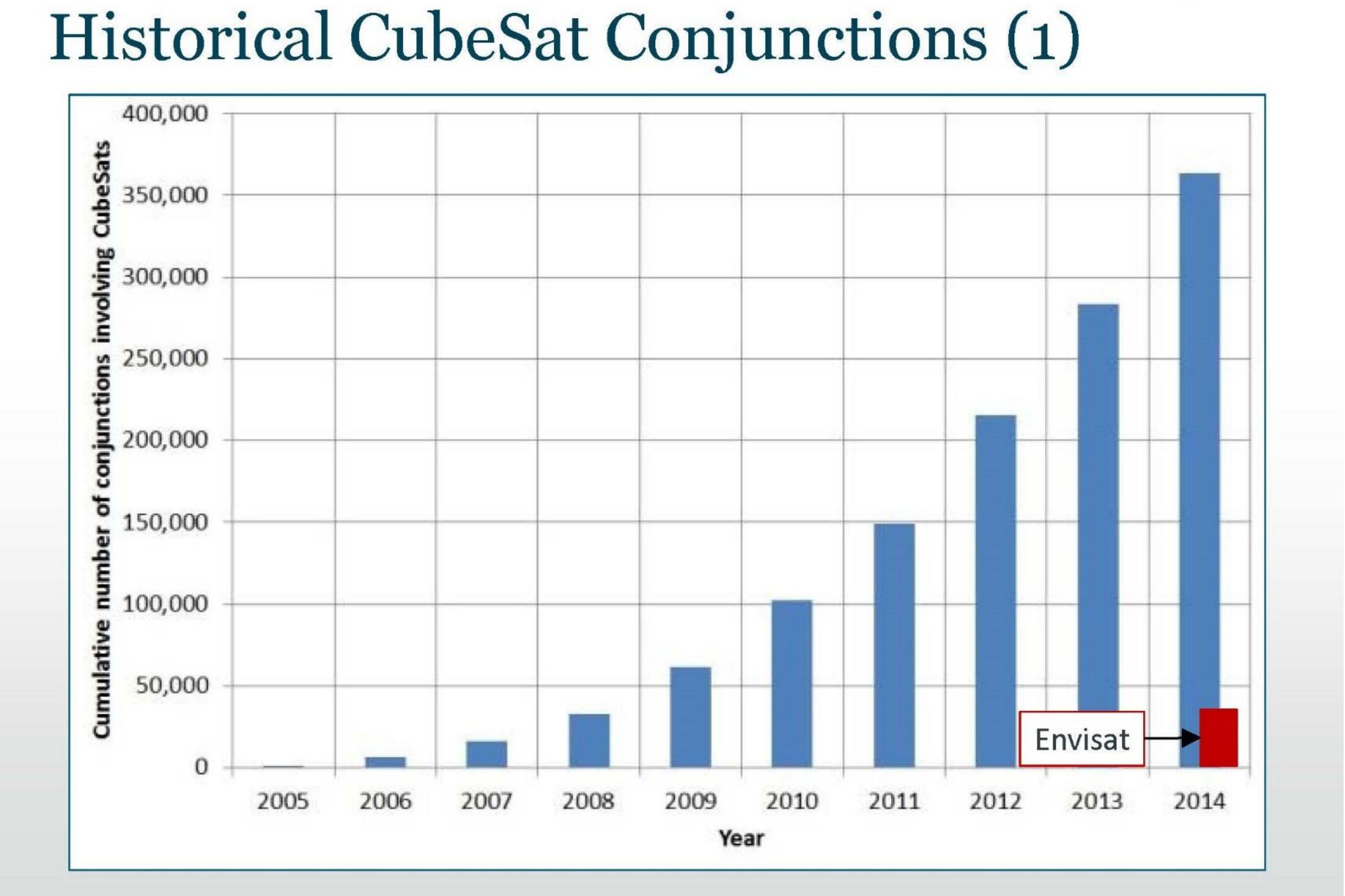
- Objectives
  - Identify/quantify the global growth trends of CubeSat-class satellite; assess the interests of US and international communities for CubeSat applications and investigate emerging CubeSat products (e.g., Planet Labs constellation of CubeSats).
  - Survey the assembly integration and testing practices of these CubeSat developers and utilize that information to investigate the mortality rates of CubeSats
  - Assess the space debris mitigation strategies utilized / implemented by these developers

Replace CubeSats with "Containerized" Satellites

Goals

- Outcomes
  - Utilize the growth trends, mortality information, and mitigation strategies to access the impact of "containerized" satellites to LEO debris
- Relevance to FAA
  - Debris in LEO will re-enter the airspace and could interact with sub-orbital flights and/or air traffic
  - Collisions with 5 mm sized debris could be consequential

Task Motivation (1/2)



Excerpted from H.G. Lewis, B.S. Schwarz, S.G. George and H. Stokes, "An Assessment of CubeSat Collision Risk," Paper IAC-14-A6.4.1, presented at 65th International Astronautical Congress, Toronto, Canada, 2014

Task Motivation (2/2)

Conclusions

- More than 360,000 conjunctions < 5 km involving CubeSats since November 2005
- Millions of conjunctions predicted to occur in the next 30 years even for relatively low CubeSat launch rates
  - Many orbital regimes in LEO are affected
  - Most likely collision scenario is CubeSat and large object in Sun-synchronous orbit
  - Relatively few collisions (< 2) predicted
- Forecasted CubeSat activity is not sustainable without

Take Away:
The sky is NOT falling – these are opportunities for us to develop innovative solutions!!

Excerpted from H.G. Lewis, B.S. Schwarz, S.G. George and H. Stokes, "An Assessment of CubeSat Collision Risk," Paper IAC-14-A6.4.1, presented at 65th International Astronautical Congress, Toronto, Canada, 2014

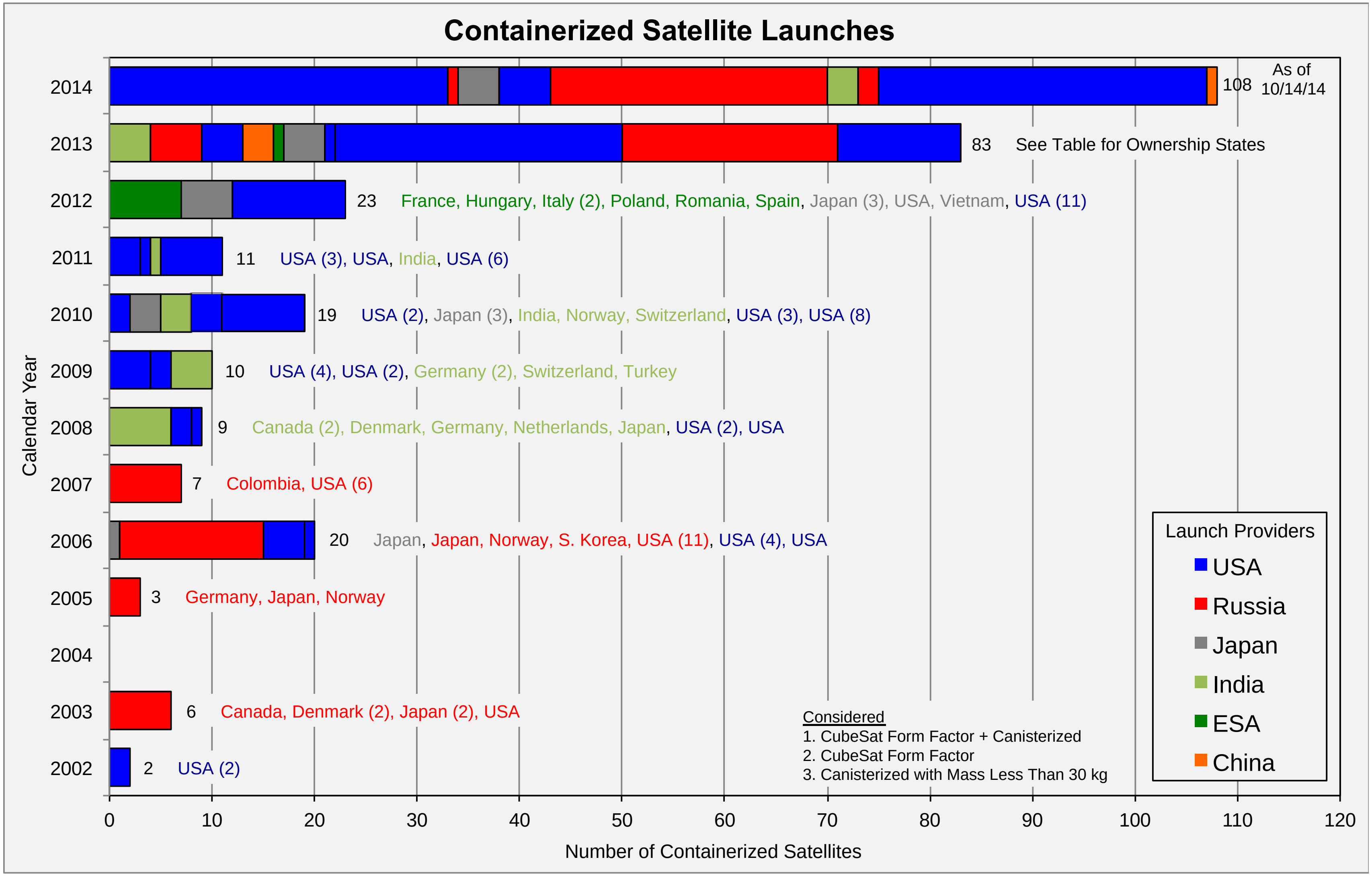
Schedule

- Start date: September 2014
- Develop survey strategy: ongoing
- Pilot test questionnaire: November 2014
- Disseminate questionnaire: January 2015
- Analyze survey results: March 2015
- Finalized results: April 2015

Approach

- Survey research process phases
  1. Identify research objectives
  2. Identify and characterize target audience
  3. Design sampling plan
  4. Design and write questionnaire
  5. Pilot test questionnaire
  6. Disseminate questionnaire
  7. Analyze results and write results

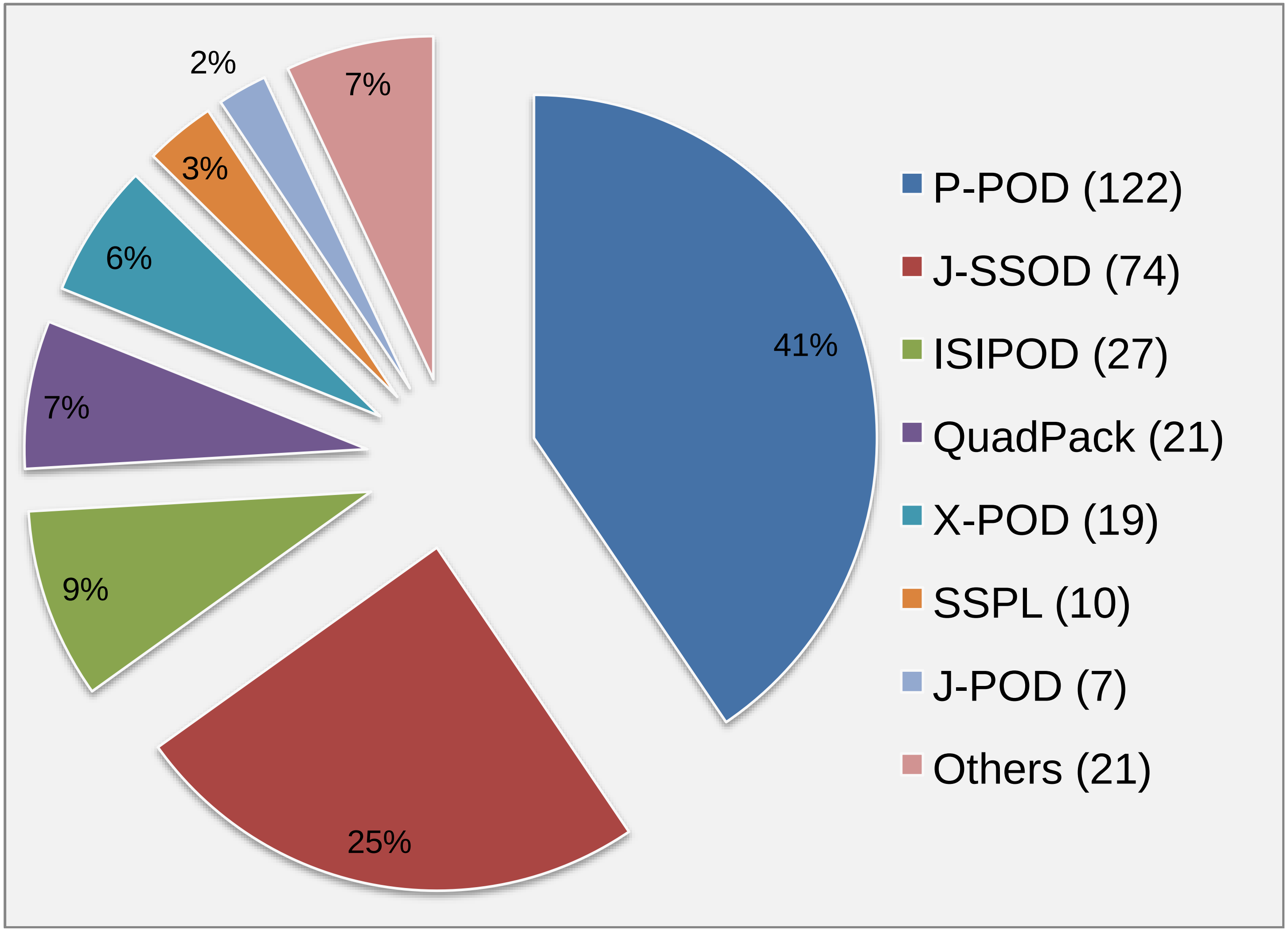
Preliminary Results



Preliminary Results

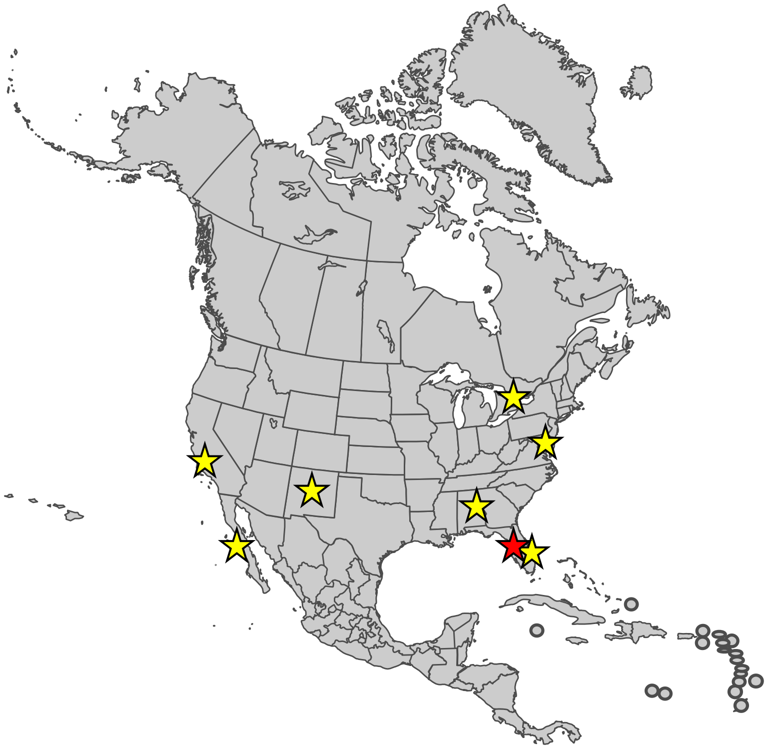
Year	Launch (Country)	#	Owner States (Country)
2013	PSLV (India)	4	Austria, Canada, Denmark, UK
	Soyuz-2 (Russia)	5	Germany (3), S. Korea, USA
	Antares 110 (USA)	4	USA (4)
	Long March 2D (China)	3	Argentina, Ecuador, Turkey
	Vega (ESA)	1	Estonia
	H-IIB (Japan)	4	USA (3), Vietnam
	Falcon-9 (USA)	1	USA
	Minotaur-1 (USA)	28	USA (28)
	DNEPR-1 (Russia)	21	INT (3), USA (2), Germany (2), Netherlands (2), Spain (2), Argentina, Denmark, Ecuador, Japan Norway, Pakistan, Poland, Peru, Singapore, S. Africa
	Atlas-V (USA)	12	USA (12)
2014	Antares 120 (USA)	33	USA (30), Lithuania (2), Peru
	Soyuz-U (Russia)	1	Peru
	H-IIA (Japan)	4	Japan (4)
	Falcon-9 (USA)	5	USA (5)
	DNEPR-1 (Russia)	27	USA (13), INT (3), Canada (2), Russia (2), Brazil, Denmark, Israel, Singapore, Taiwan, Ukraine, Uruguay
	PSLV (India)	3	Canada (2), Singapore
	Soyuz-2 (Russia)	2	Norway, UK
	Antares 120 (USA)	32	USA (31), Greece
	Long March 4B (China)	1	Poland

Preliminary Results



Others include, T-POD, Dragon, SPL, PEPOD, CSS, FlyMate, CSD, Hand deployment from ISS, Unknowns

Dissemination Strategy (1/2)



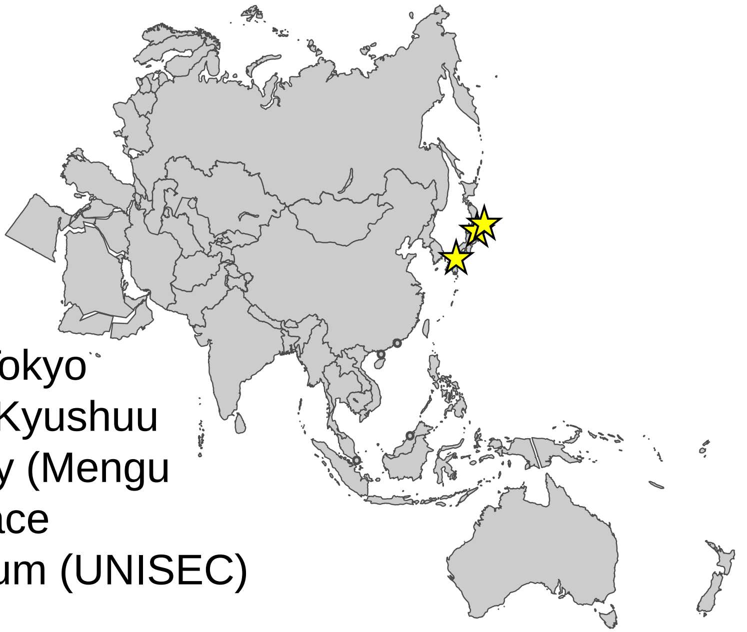
North America
- CubeSat Listserve, CalPoly
- USA: AIAA SmSTC, AMSAT, AFRL, NRO, NSF, NASA, SMDC, SMC, universities
- Canada: University of Toronto, Canada (Freddy Pranajaya)

South America
- Brazil: Brazilian Space Agency (AEB), INPE (Otavio Durao)
- Columbia (Camilo Guzman Gomez)
- Mexico (Carlos Duarte)

Dissemination Strategy (2/2)

<u>Africa</u>

- South Africa: CPUT (Robert van Zyl)
- Ghana: ANU (Quarshie Manfred)

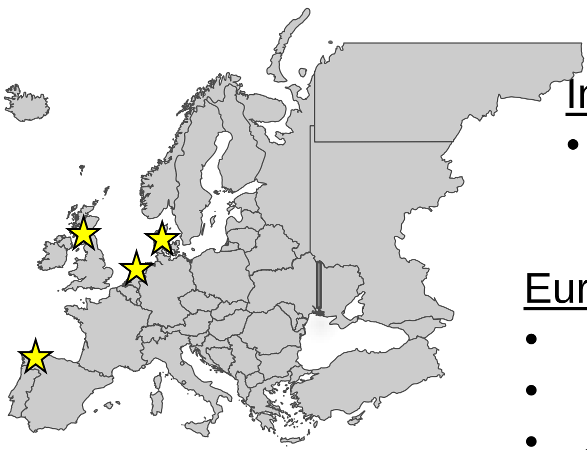


<u>Asia</u>

- Japan: University of Tokyo (Shinichi Nakasuka), Kyushuu Institute of Technology (Mengu Chou), University Space Engineering Consortium (UNISEC)

<u>India</u>

- TBD



<u>Europe</u>

- Denmark (GomSpace Aps)
- Netherlands (Innovative Solutions in Space)
- Spain (University of Vigo)
- United Kingdom (Clyde Space Ltd, Univ. of Leicester)

Draft Survey Questions (1/7)

To be disseminated to containerized satellite developers and operators.

- A containerized satellite is any satellite that is enclosed in a separate structure/volume that interfaces between the satellite and the launch vehicle. Such container may contain one or more satellites and prevents any harm to the primary, launch vehicle, or other secondary satellites

Draft Survey Questions (2/7)

1. Is your team/group a designer, developer, and/or manufacturer of containerized satellites?

   ✔ Yes　　　o No

1-A. Have any of your team/group's containerized satellites been launched?

   ✔ Yes　　　o No

1-A-1. Select the mass range(s) which accurately describe your satellites. For each range, please note the number of satellites.

Mass	Count
Less than 1 kg	0
1 kg to 10 kg	1 to 5
10 kg to 100 kg	0
100 kg to 500 kg	0
Greater than 500 kg	0

0
1 to 5
More than 5

Draft Survey Questions (7/7)

3. Please select activities that your team/group has conducted for quality assurance of your satellite(s). Select all that apply.

- o Simulations and analysis
    - o Structural and Thermal
    - o Orbital
    - o Functionality
- o Functionality testing of hardware and software
- o Reliability analysis
- o Requirements verification matrix (i.e., traceability)
- o Internal(peer) and external(subject matter experts) reviews
- o Configuration management
- o Systems engineering process
- o Others (Please briefly describe):

Optional questions

Name of satellite(s), Name of container(s), Size of team/group, Team/Group's association (academia, industry, government), Mission description, etc

TASK #244. Autonomous Rendezvous & Docking for Space Debris Minimization

UF UNIVERSITY of FLORIDA

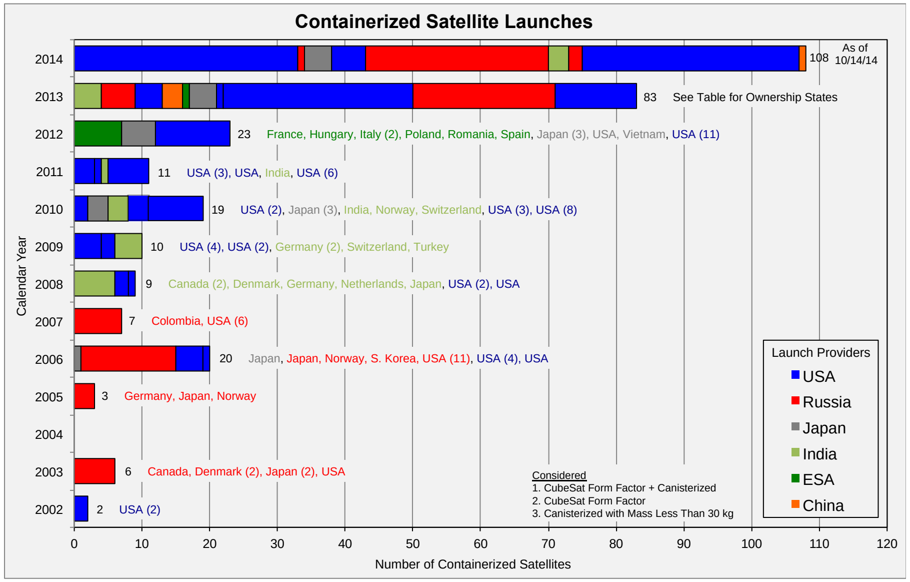
- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Stephen Earle, Ken Davidian
- UNIVERSITY: University of Florida
- PRINCIPAL INVESTIGATOR: Dr. Norman Fitz-Coy
- STUDENT(s): Tristan Newman (MS)

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- The proliferation of small satellites will eventually contribute to space debris and thus methodologies for the mitigation and remediation of space debris are required. The 2010 US Space Policy strongly encourages the development of commercial capabilities to enhance safe space operations.

STATEMENT OF WORK

- The objective of this research effort is the development of computationally efficient and robust methodologies for active space debris remediation. As this research proceeds, it is expected to make the following contributions:
- Development of artificial potential function-based guidance (APFG) algorithms for proximity operations and autonomous rendezvous/docking.
- Development of strategies to minimize the interactions between a rescue spacecraft and a non-cooperative (disabled) spacecraft. These strategies will be based on game theoretic strategies.
- Modification (Sept. 2014): Assess the impact of launch rate and satellite densities (i.e., number of satellites launched simultaneously) on LEO debris growth and identify strategies to mitigate debris growth caused by containerized satellites



STATUS

- Identified some potential impact factors (e.g., launch rate, satellites per launch, orbit, etc)
- Drafting survey questions
- Identified POC for dissemination of survey

FUTURE WORK

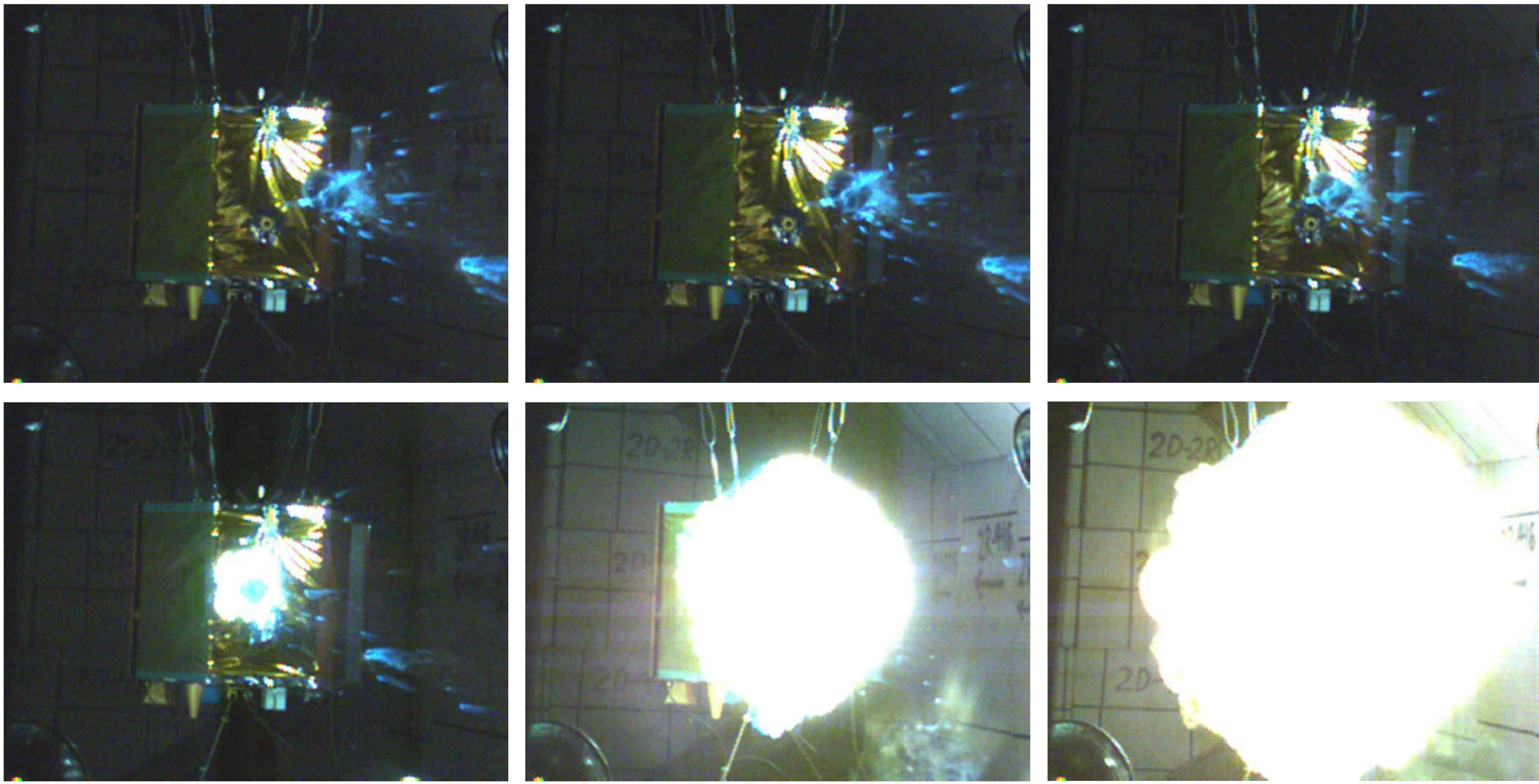
- Survey the “containerized” satellite community to assess their impact on space debris in LEO
- Complete analysis of survey results
- Report findings to FAA, NASA ODPO, IADC, AIAA SmSTC

DebriSat – Hypervelocity Impact

- Performed at USAF Arnold Engineering Development Complex Range-G which operates the largest two-stage light gas gun in the U.S.
- Diagnostic instruments include X-rays, high-speed Phantom cameras, lasers, IR cameras, piezoelectric sensors, witness plates, etc
- Polyurethane foam panels of various densities were installed inside target chamber to “soft catch” fragments

DebriSat – Hypervelocity Impact

- **DebriSat hypervelocity impact conducted on April 15, 2014**
  - Projectile travelling at 6.8 km/sec at impact with DebriSat
  - Impact released 13.2 MJ of energy



DebriSat – Hypervelocity Impact

- **After impact, all intact foam panels, broken foam pieces, loose fragments, and dust were carefully collected, documented, and stored**
  - Estimated ≥ 2 mm DebriSat fragments are on the order of 85,000
  - All fragments will be characterized and used to update orbital debris models