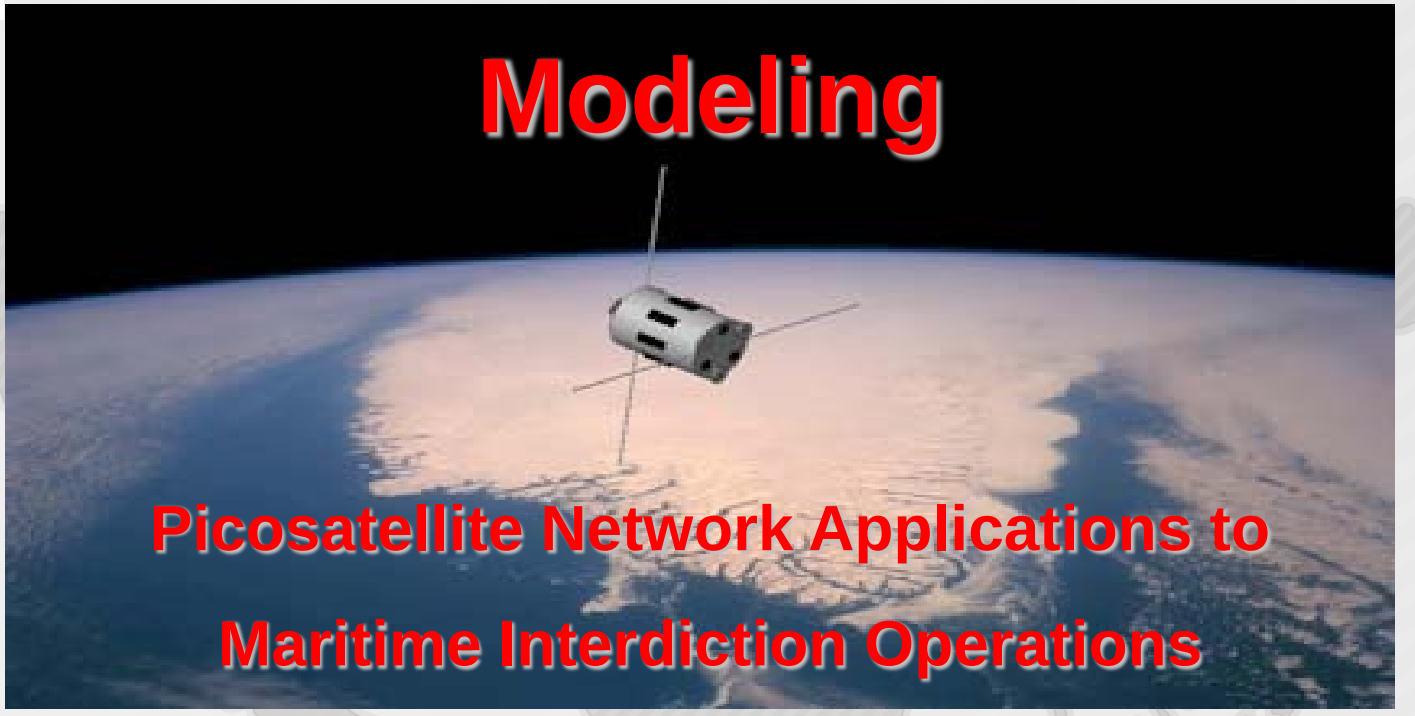
Modeling



Picosatellite Network Applications to Maritime Interdiction Operations

by **Dr. Alex Bordetsky**

Georgios Mantzouris, Ph.D. candidate

Center for Network Innovation and Experimentation (CENETIX)
Department of Information Sciences
Naval Postgraduate School
Monterey, CA 93940

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Abstract

- Provide Effective, Efficient and Affordable existing applications of Pico satellite technology to the maritime awareness tasks.

- Develop Picosatellite node experiments

- Use of an STK software model of future miniature orbital tactical nodes to simulate the implementation in Maritime Interdiction Operations (MIO) scenarios

Presentation Outline

1. Paper Abstract
2. Objectives
3. Conceptual Model
4. Pico Mission Critical Parameters
5. Results
6. Conclusion and Future Work

Objectives

1. Space based tactical networking to provide collaboration between on scene commanders and Subject Matter Experts in remote locations.
2. Find approaches to provide solutions to intractable threats such as illicit trafficking, piracy and WME.
3. Implement experiments of MIO testbed to explore challenging solutions for monitoring threats (e.g. via LEO picosats)

Conceptual Model

MIO Reachback Needs and Requirements

1. Reachback capabilities in the Real Time area
2. Accurate identification of possible fissile materials to boarding team members
3. Present day: Fusion Center comms via radio with tactical command – Method not rapid nor reliable
4. Our approach: Afloat officer to communicate directly with Fusion Center via collaborative technology

Conceptual Model

MIO Reachback Needs and Requirements

5. Advantages: Rapid, Reliable, Efficient comms with technical experts in the Fusion Center.

6. MIO advising upon request leads to mission success

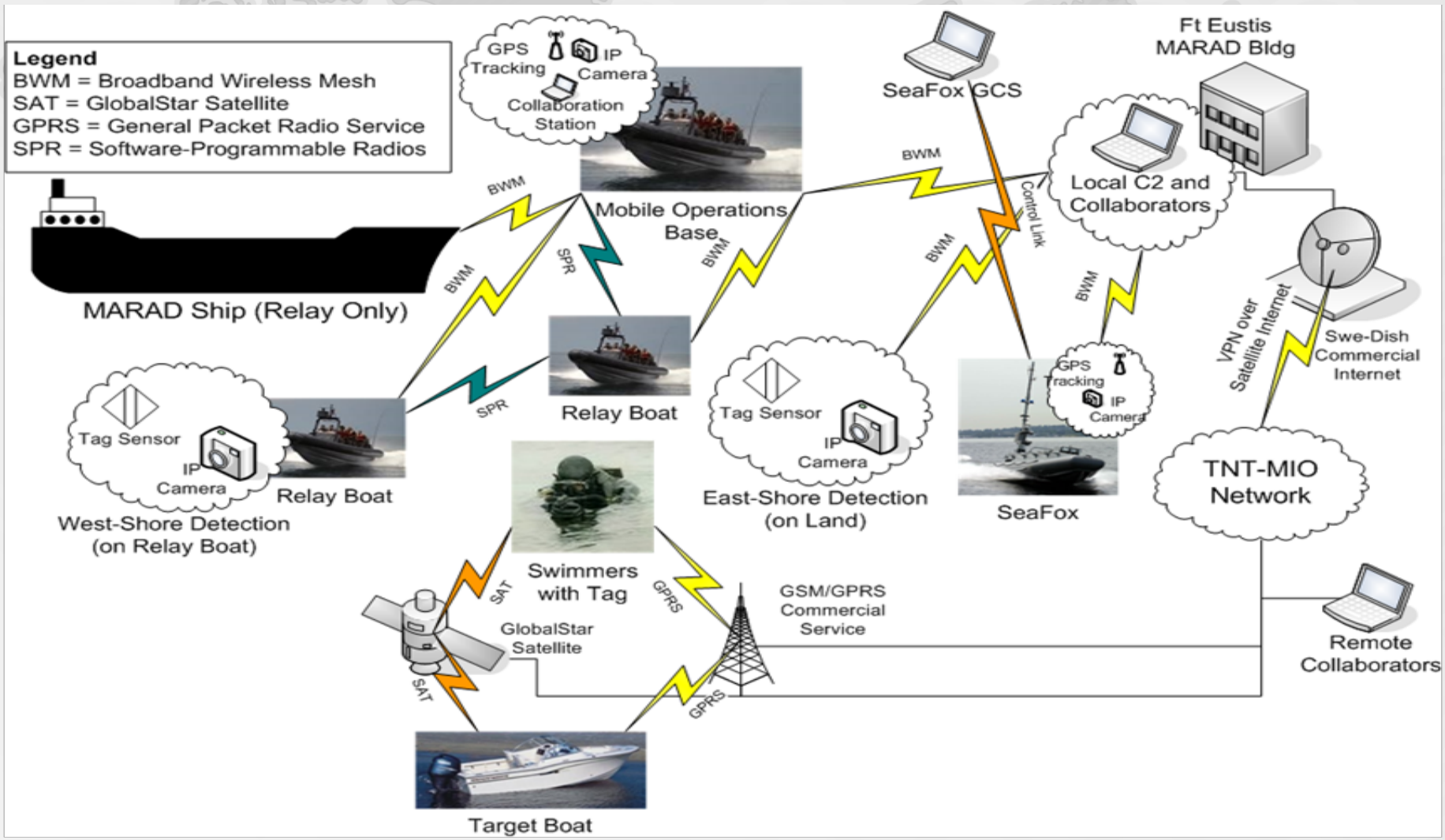
Picosatellite Characteristics Critical to MIO Support

1. Picosatellite System by Interorbital Co, named Tubesat
2. Standalone Picosatellite with minor capability of data networking, space imaging and payload
3. 310 km circular polar orbit
4. Orbital longevity of 3 weeks to 3 months
5. Orbital decay parameter affect lifetime

Picosatellite Characteristics Critical to MIO Support

6. Real Time or asynchronous data action officer on the move networking
7. Reachback capability with connection to MIO expert or C2 team ashore
8. Maximize coverage with the use of 4-6 picosatellites
9. Very low cost application easily replaceable

Tubesat and NPS MIO Testbed



Pico – Mission Critical Parameters

- Satellite Operational Lifetime.
- Real or Near Real time Tracking Capabilities.
- Accuracy of Tracking.
- Available Data Transmission Techniques.
- Available Data Channels.
- Operating Principles of small satellites.
- Tactical Implications in MIO
- Video Capability.
- Reach Back Capability.
- Serve humanitarian missions

Pico – Operational Characteristics

- Types of orbits (equatorial – polar for small sats)
- Footprints.
- Segments that use and provide.
- Lifetime consideration.
- Time of Revisit.
- Services that is able to provide such as SMS / FAX / Teleconference – Video.
- Security that is being enabled.
- Available data rate.
- Probability to establish a call.
- Probability of maintaining a call for LEO – Small satellites.
- Back up satellites for service if needed.
- Ability for crosslink with Pico sats to transfer data if needed.
- Ability of global coverage.

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STK
Modeling of Tubesat

Assumptions

• The boarding officer needs to communicate via Picosatellite nodes in a near real time environment providing information to experts ashore and receive an advice back.

• The boarding officer locates the material but he does not know how to handle it. He sends all collected information to a Fusion Center.

• Modeling of four and six Tubesat type picosatellite integration capability

Modeling of a 4 Tubesat mission

Orbital Elements	Apogee Altitude *Constant for TUBESAT (km)*	Perigee Altitude *Constant for TUBESAT (km)*	Inclination *(Polar orbit)*	Argument of Perigee *(Circular Orbit)*	RAAN	True Anomaly *(Circular Orbit)*
PICOMIO 1	310	310	90	0	0	0
PICOMIO 2	310	310	90	45	45	0
PICOMIO 3	310	310	90	90	90	0
PICOMIO 4	310	310	90	135	135	0

Table 1: Orbital Characteristics for TUBESAT mission using 4 Picosatellites

Modeling of a 6 Tubesat mission

Orbital Elements	Apogee Altitude *Constant for TUBESAT (km)*	Perigee Altitude *Constant for TUBESAT (km)*	Inclination *(Polar orbit)*	Argument of Perigee *(Circular Orbit)*	RAAN	True Anomaly *(Circular Orbit)*
PICOMIO 1	310	310	90	0	0	0
PICOMIO 2	310	310	90	45	45	0
PICOMIO 3	310	310	90	90	90	0
PICOMIO 4	310	310	90	135	135	0
PICOMIO 5	310	310	90	180	180	0
PICOMIO 6	310	310	90	225	225	0

Table 2: *Orbital Characteristics for TUBESAT mission using 6 Picosatellites*

Picosatellite Integration Modeling Results

Simulation Dates: 6 and 7 June
No of Picosats: Four (4)
Total Available time: 120 minutes per day

Date	Satellite	Passes / Satellite	Time (GMT)	Duration (min)
6th June	PICOMIO 1	4	05:09:41 - 05:18:35 06:43:08 - 06:47:11 16:14:30 - 16:20:26 17:44:02 - 17:52:40	9 4 6 8
	PICOMIO 2	3	07:49:59 - 07:58:18 09:21:23 - 09:28:11 20:22:44 - 20:31:42	9 7 9
	PICOMIO 3	4	00:33:12 - 00:38:50 10:40:23 - 10:48:15 12:11:05 - 12:18:38 23:12:53 - 23:21:50	6 8 7 9
	PICOMIO 4	4	01:51:42 - 02:00:08 03:22:56 - 03:29:33 13:30:53 - 13:38:10 15:00:54 - 15:08:59	8 7 8 8
Total	-	15	-	113 min
7th June	PICOMIO 1	4	03:56:26 - 03:58:52 05:23:18 - 05:32:17 16:27:31 - 16:35:02 17:58:00 - 18:05:53	2 9 7 7
	PICOMIO 2	4	08:01:13 - 08:10:01 09:33:58 - 09:38:56 19:05:20 - 19:10:30 20:34:21 - 20:43:07	9 5 5 9
	PICOMIO 3	5	00:46:00 - 00:48:47 10:51:31 - 11:00:03 12:23:24 - 12:29:36 21:56:17 - 21:59:38 23:24:26 - 23:33:21	2 9 7 2 9
	PICOMIO 4	4	02:03:04 - 02:11:55 03:35:14 - 03:40:01	8 5
Total	-	17	-	111 min

Table 3: Overall MIO scenario results with the use of 4 PICOMIO satellites on June 6th and 7th

Results

Four (4) Picosats

- Vital Time delay structure for boarding officer reachback communications
- On a given day 12 or 18 consecutive orbits for use
- Time over the ground station from 2 to 9 minutes
- Operational use of the system 2 hours per day

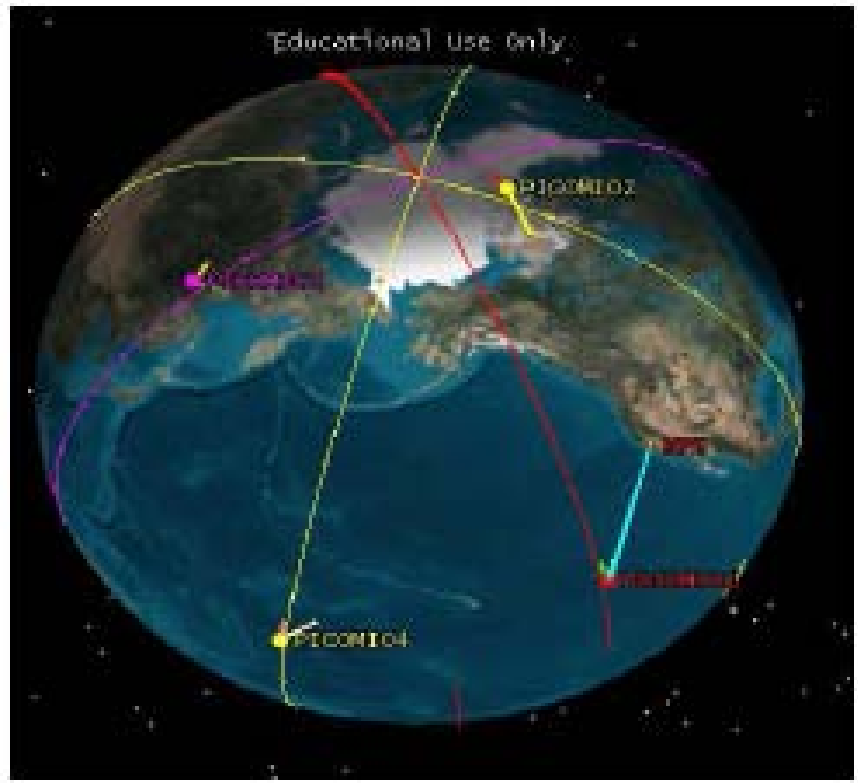
Operational Gaps

Operational Gap per day is 22,5 hours

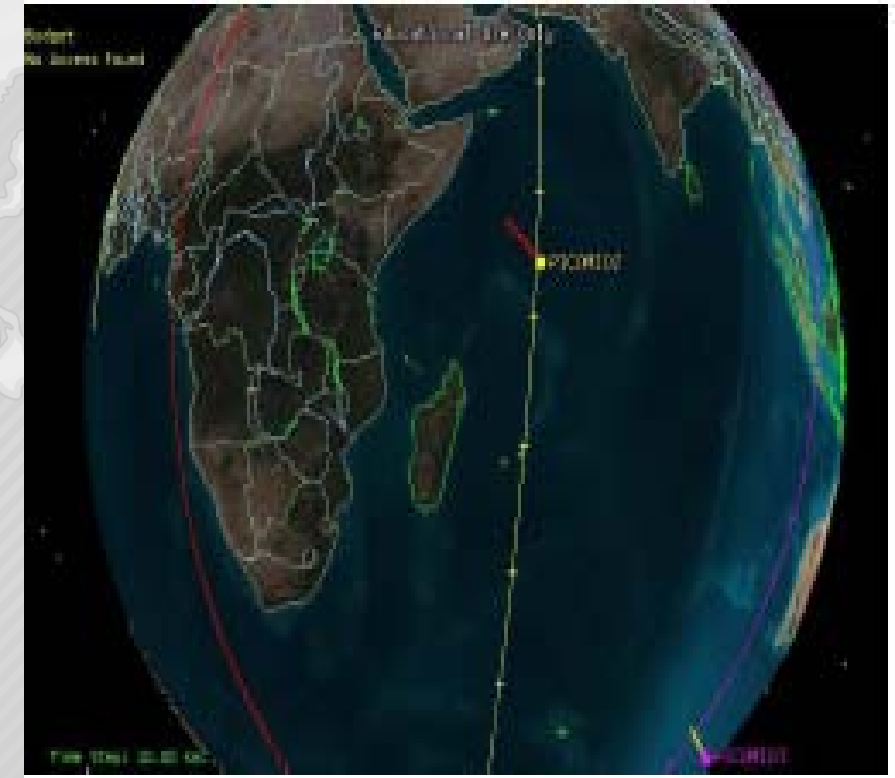
6th June 2011
Total Gap Timeframe in one day

Start Time of Pass	End Time of Pass	Gaps among passes
00:33:12	00:38:50	1 h 10 min
01:51:42	02:00:08	1 h 22 min
03:22:56	03:29:33	1 h 40 min
05:09:41	05:18:35	1 h 25 min
06:43:08	06:47:11	1 h 02 min
07:49:59	07:58:18	1 h 23 min
09:21:23	09:28:11	1 h 12 min
10:40:23	10:48:15	1 h 23 min
12:11:05	12:18:38	1 h 12 min
13:30:53	13:38:10	1 h 22 min
15:00:54	15:08:59	1 h 06 min
16:14:30	16:20:26	1 h 24 min
17:44:02	17:52:40	2 h 30 min
20:22:44	20:31:42	2 h 41 min
23:12:53	23:21:50	-
≈ Total Gap Time in one day		22 , 5 hours

STK representation



Allocation of picosatellite orbits in the scenario



PicoMIO 2 passing over the area of MIO in the Somali Basin acquring data from a boarding officer and send it back to a fusion Center in US

Total Coverage Time

- Use of four (4) or six (6) Tubesats from 4 to 12 July

- Adding two more satellites to the MIO testbed we increased the total daily time coverage by 3 - 4 %

- Approximately 1 hour and 20 minutes per day

Dates June 2011	Daily Percent Time Covered 4 Pico-Satellites	Daily Percent Time Covered 6 Pico-Satellites
4	7.00	11.32
5	7.17	11.84
6	8.10	11.81
7	7.92	11.66
8	7.96	11.66
9	7.77	10.14
10	7.23	10.15
11	7.52	11.51
12	7.62	11.67

Orbital Decay

Characteristics

Orbital Decay Characteristics	Value
Cd	2.033
Cr	1.33
Drag Area	0.01365 m^2
Area Exposed to Sun	0.01543 m^2
Mass	1 kgr
Atmospheric Density	Jacchia 1970 model
Solar Flux sigma level	0

- **Picosatellite will remain on orbit a little over a month ranging from 30 -33 days**
- **527 to 528 available orbits**
- **Best case scenario changes the number of orbits only for one or two orbits**

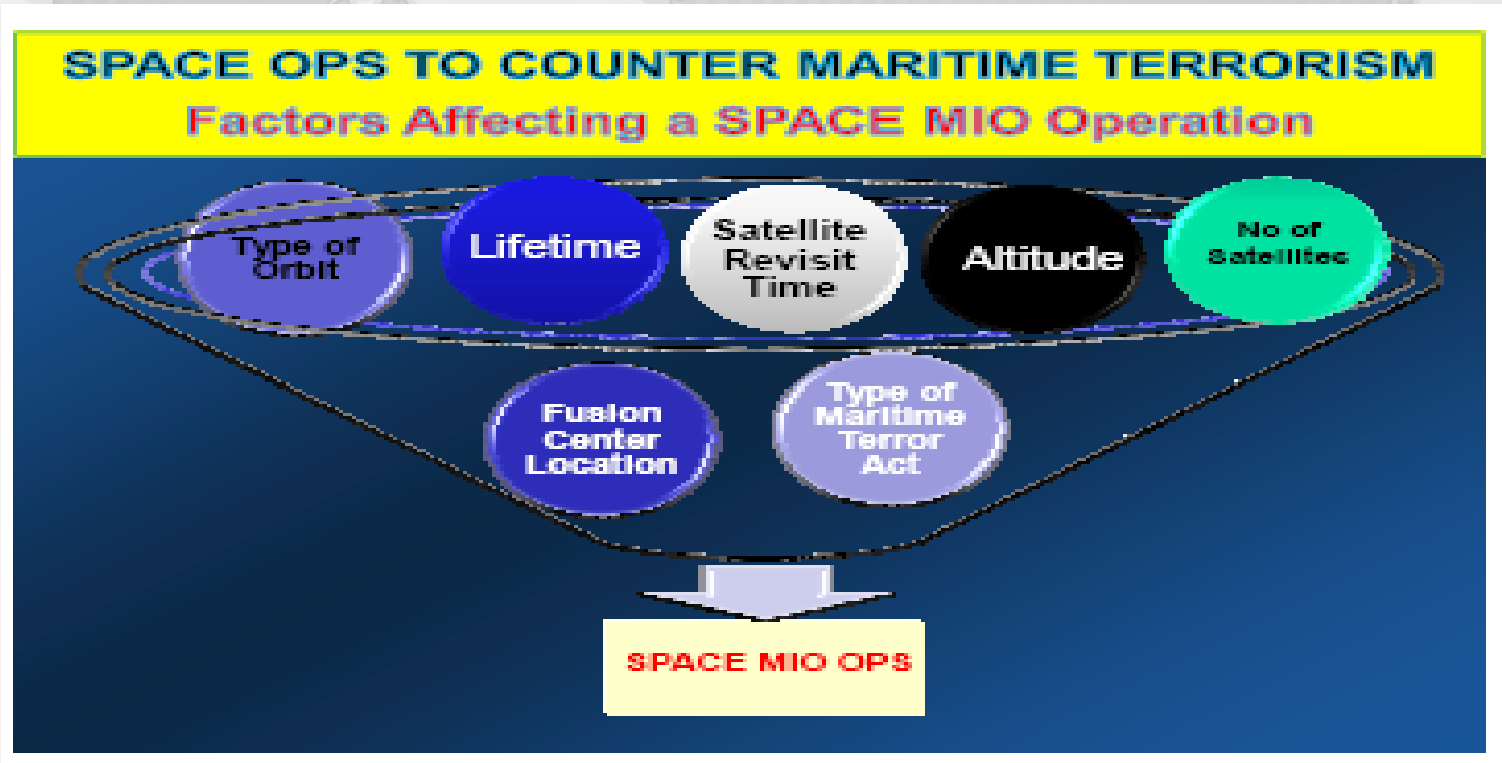
Pico Satellite	Date *(June)*	Time *(GMT)*	Orbits *(in one month)*	Lifetime *(in days)*
PICOMIO1	4	07:39:32	527	33
PICOMIO2	3	19:28:47	528	32
PICOMIO3	2	05:54:02	503	31
PICOMIO4	2	07:29:36	504	30

Conclusions

1. Six Picosatellites in Polar orbit would provide effective communication window for boarding officer
2. Two and a half hours availability of communication – enough for applying reachback methods
3. Field officers need this capability in order to enhance their mission success
4. Picosatellite based networking model contributes to the emerging concept of Space Operations to Counter Maritime Terrorism

Funnel Approach Factors

Emerging Concept of Space Ops to Counter Maritime Terrorism



Future Work

- Launch of Picosatellites in the third Quarter of 2011
- Evaluation of STK model through MIO exercise / experimentation from NPS – LLNL MIO experts
- Comparison of real acquired data with the operational need
- Creation of future milestones to support NATO MIO operations

Questions – Discussion …

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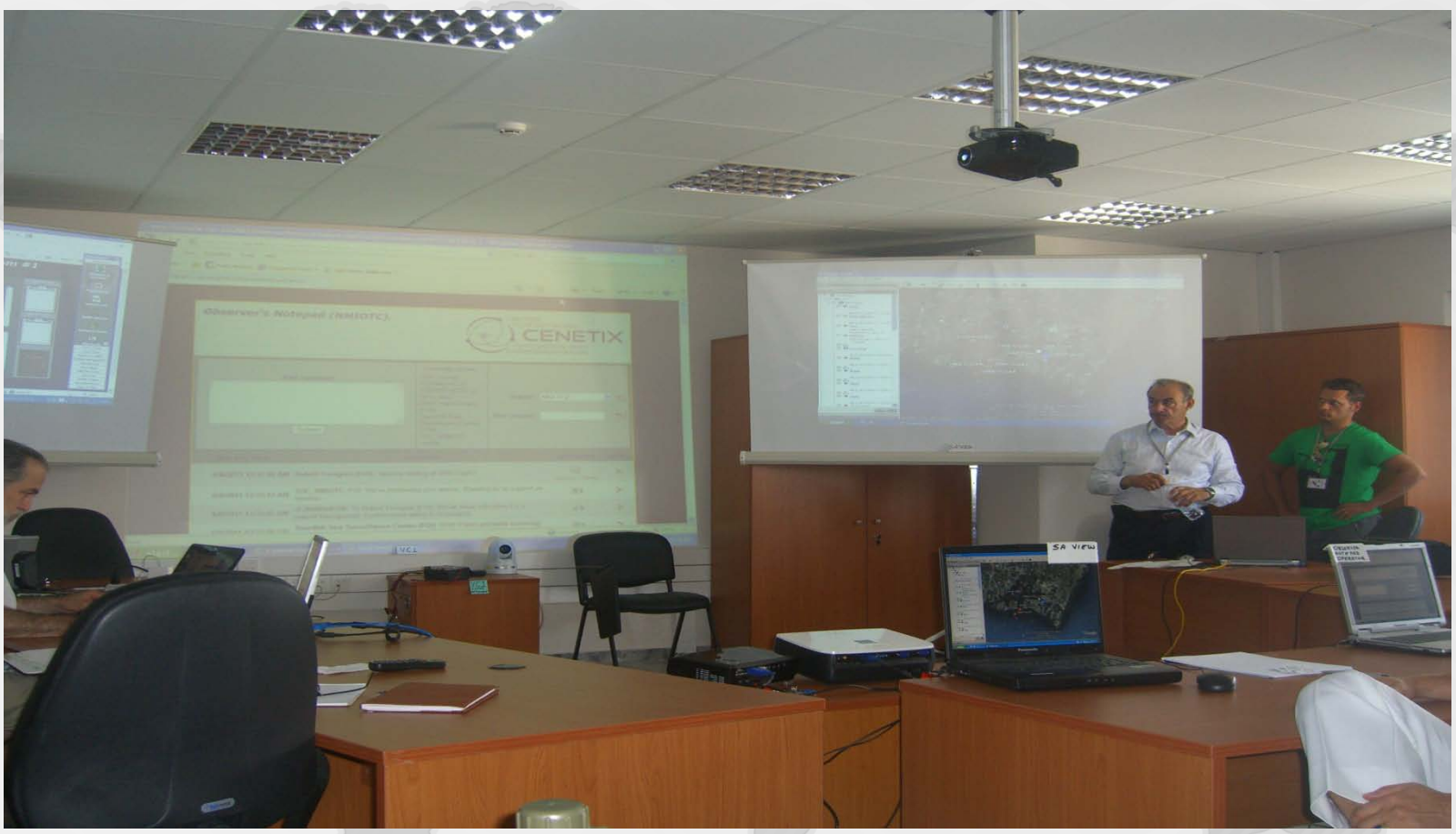

NPS and LLNL experts set up mobile tactical operational fusion centers and communicate / evaluate with field boarding officers during MIO exercises / experiments