Functionalities & Developments in Sensor Networks

Presented at the
Government-Industry-University
Research Roundtable (GUIRR) Meeting
February 23, 2010

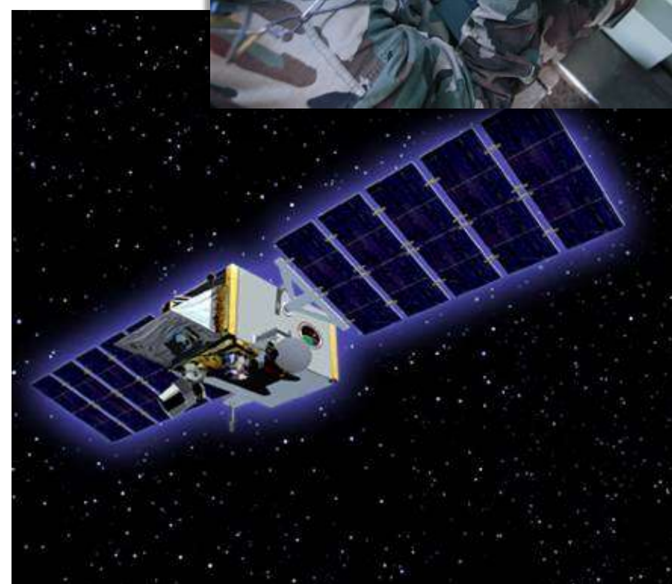
Leonard Poveromo, Technology Director
Robert P. Silberstein, Tech Fellow
Technology Development
Northrop Grumman Aerospace Systems
Bethpage, NY

Outline

- Northrop Grumman today
- The people who really did this work
- Sensors for Aircraft: Prognosis and Health Monitoring
- New Ground Sensors: Infrasound
- Emerging Platforms: Unmanned Aerial Vehicles (UAVs)
- New Airborne Sensors: LIDAR
- Air & Space Remote Sensing: Hyperspectral Airborne Tactical Instrument (HATI)
- Back to Earth: Sensor Systems for Homeland Security
- Future Technologies: Wireless Power
- Technology Collaborations / Lessons Learned

Northrop Grumman Today

- $34 billion sales in 2008
- $78 billion total backlog
- 120,000 people, 50 states, 25 countries
- Third largest U.S. defense contractor
- Leading capabilities in:
  - Systems integration
  - C4ISR and battle management
  - Information technology and networks
  - Defense electronics
  - Naval shipbuilding
  - Space and missile defense



Focus on Performance

Northrop Grumman Today

Aerospace Systems

Large Scale Systems Integration

C^4ISR

Unmanned Systems

Airborne Ground Surveillance / C2

Naval BMC2

Global / Theater Strike Systems

Electronic Combat Operations

ISR Satellite Systems

Missile Defense Satellite Systems

MILSATCOM Systems

Environmental & Space Science Satellite Systems

Directed Energy Systems

Strategic Space Systems

Electronic Systems

Radar Systems

C^4ISR

Electronic Warfare

Naval & Marine Systems

Navigation & Guidance

Military Space

Government Systems

Information Systems

Command & Control Systems

Network Communications

Intelligence, Surveillance & Reconnaissance Systems

Enterprise Systems and Security

IT/Network Outsourcing

Intelligence

Federal, State/Local & Commercial

Homeland Security & Health

Shipbuilding

Naval Systems Integrator

Surface Combatants

Expeditionary Warfare Ships

Auxiliary Ships

Marine Composite Technology

Coast Guard Cutters

Commercial Ships

Nuclear Aircraft Carriers

Nuclear Submarines

Fleet Maintenance

Aircraft Carrier Overhaul & Refueling

Technical Services

Systems Support

Base and Infrastructure Support

Range Operations

Maintenance Support

Training and Simulations

Technical and Operational Support

Live, Virtual and Constructive Domains

Life Cycle Optimization

Performance Based Logistics

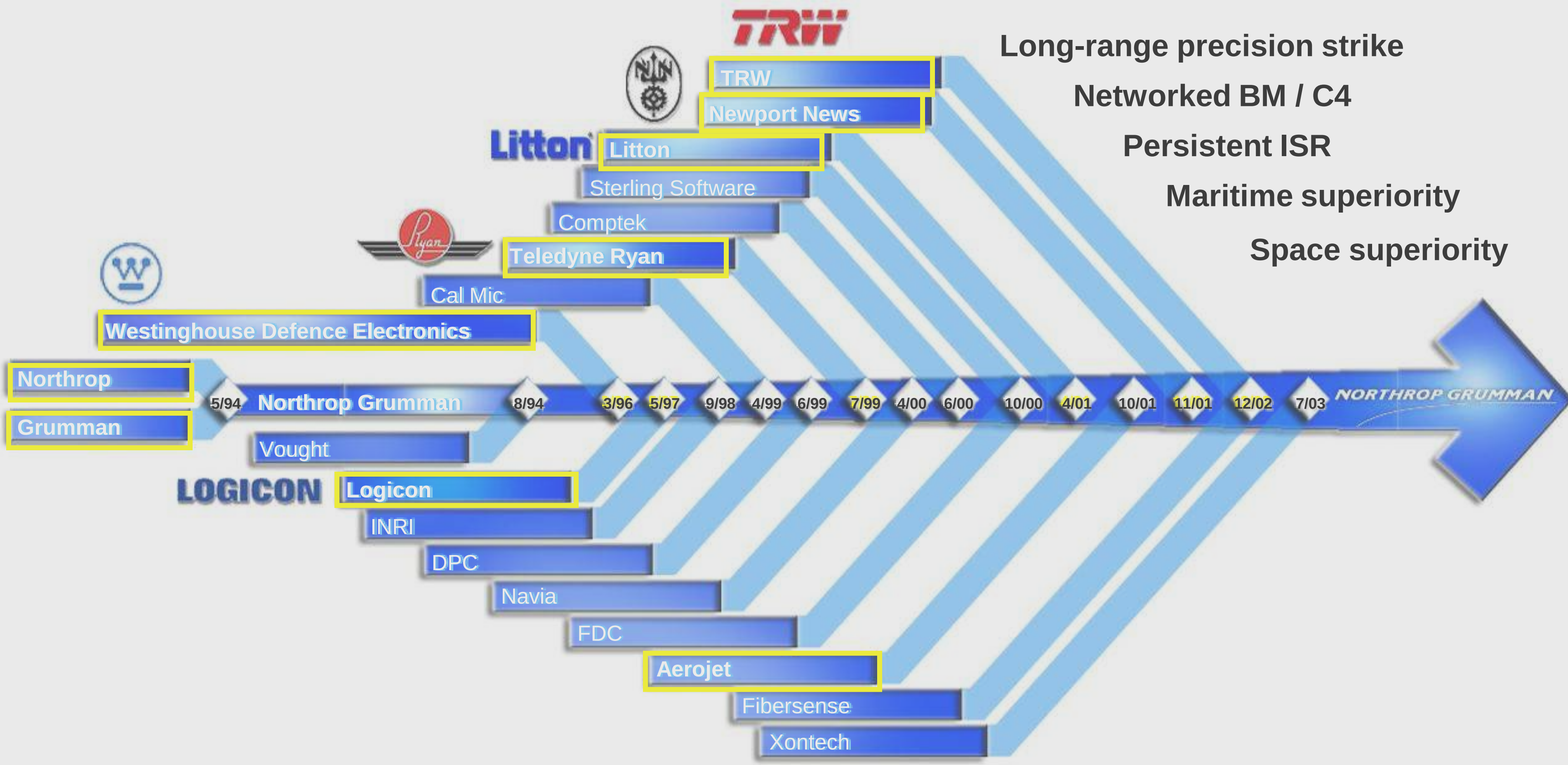
Modifications, Repair and Overhaul (MRO)

Supply Chain Management

Lead Support Integrator (LSI)

Five Operating Sectors

Transformation of Northrop Grumman



Once "merely" a combat aircraft company, now a systems integrator with a broad portfolio supporting defense transformation

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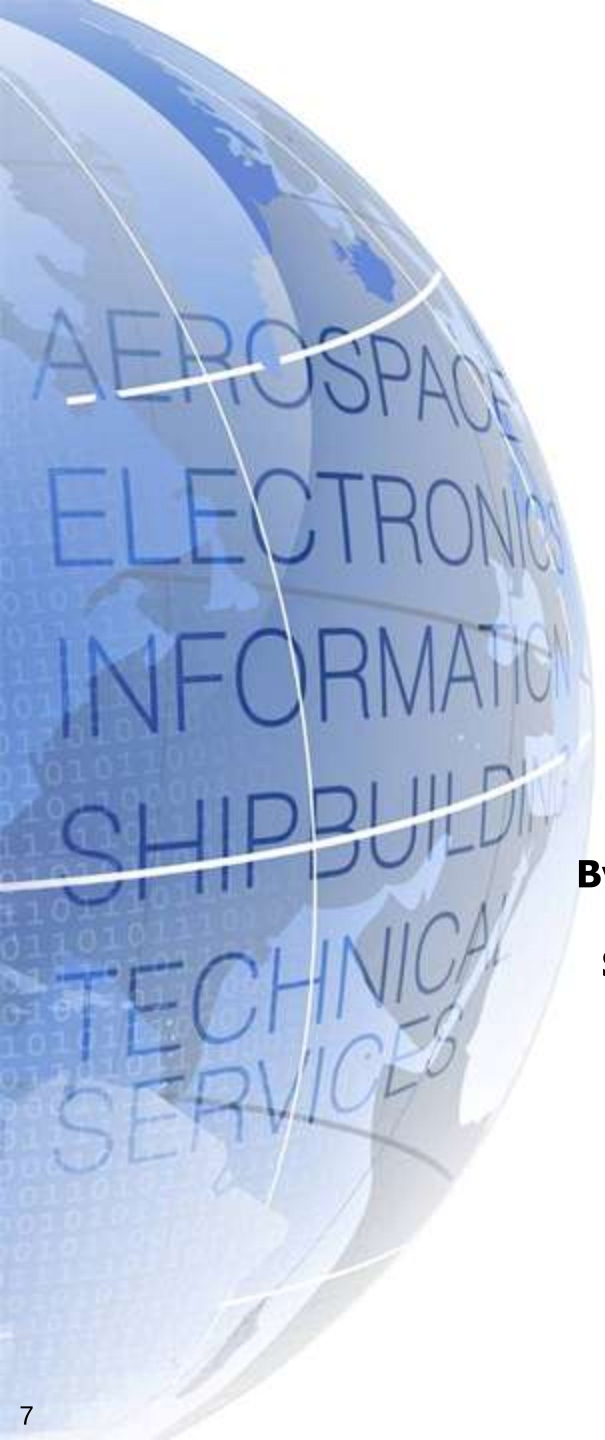

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Sensors for Aircraft Prognosis

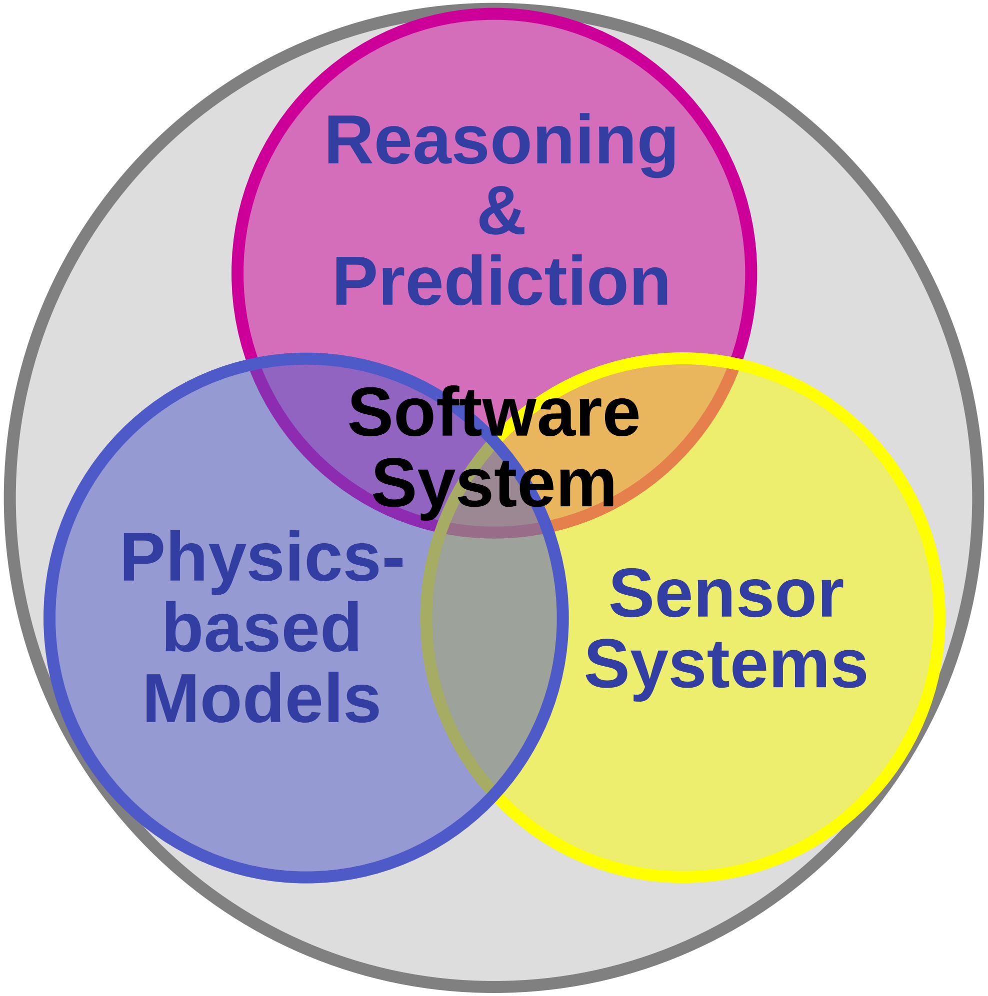
From: "Sensor Systems for Real-time Crack Monitoring and Structural Prognosis During Full Scale Fatigue Test of an Aircraft Wing Panel," ASNT 17th Annual Research Symposium, 2008,

By R. Silberstein, R. J. Christ, Jr., S. J. Engel, J. Madsen, J. Nardiello, J. Papazian, J. Payne, B. Pember (Northrop Grumman Aerospace Systems); and contributors from GA Tech, JENTEK Sensors Inc., U. of PA, Direct Measurements Inc., & Oceana Sensor Technologies;

And from: "Prognostics Health Management – An Engineering Perspective," Prognostics Health Management Conference, September 2009

By Stephen J. Engel
Stephen.Engel@NGC.com
Northrop Grumman Aerospace Systems

Structural Integrity Prognosis System (SIPS)



- Combine knowledge of fatigue processes, current state, and history of an aircraft
- Develop models, sensors, and reasoning systems
- Increase asset availability and reduce cost without increasing risk
- DARPA funded program

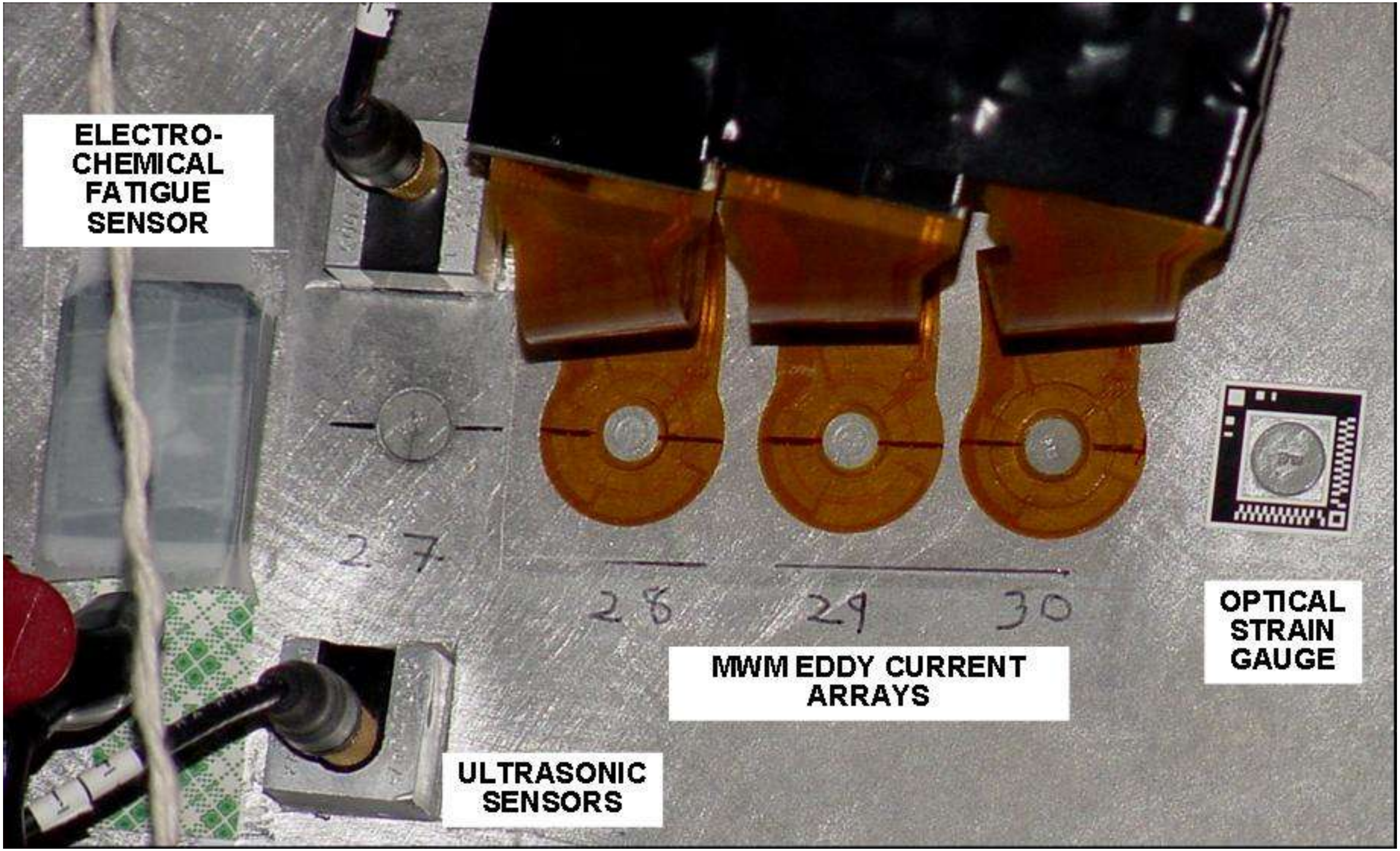
Robert.Silberstein@NGC.com, Stephen.Engel@NGC.com

Overall Goals for Sensor Systems

- Detect earliest incipient material damage
- Utilize real-time data for model calibration and validation
- Exploit correlated multi-sensor data for improved measurement sensitivity and model applicability
- Develop techniques to optimize the selection and placement of sensors for different applications
- Apply sensor systems in full-scale fatigue test for model calibration and verification
- Demonstrate sensor systems in long-term and real-time application for SIPS

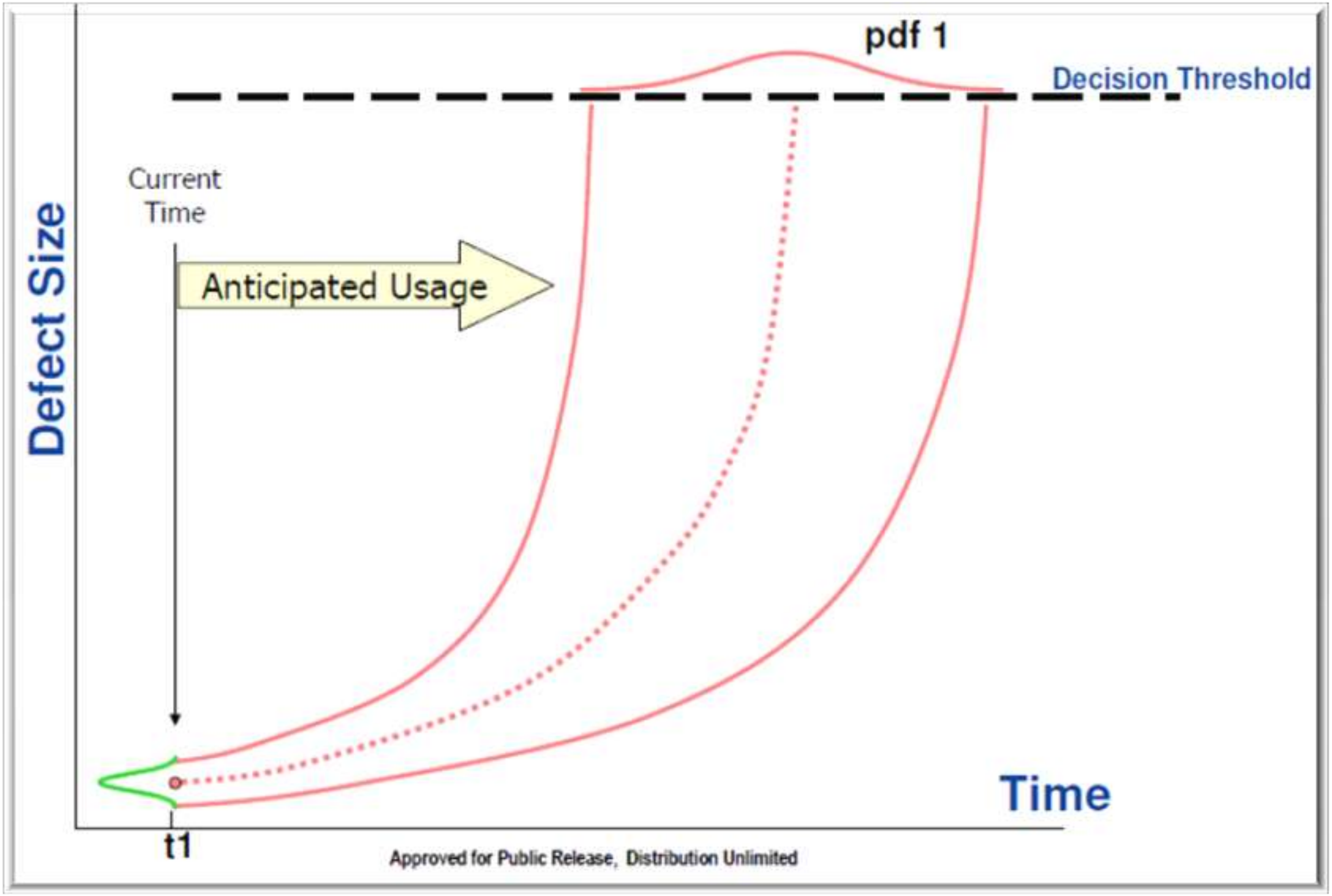
Robert.Silberstein@NGC.com, Stephen.Engel@NGC.com

Sensor Placement on Wing Panel



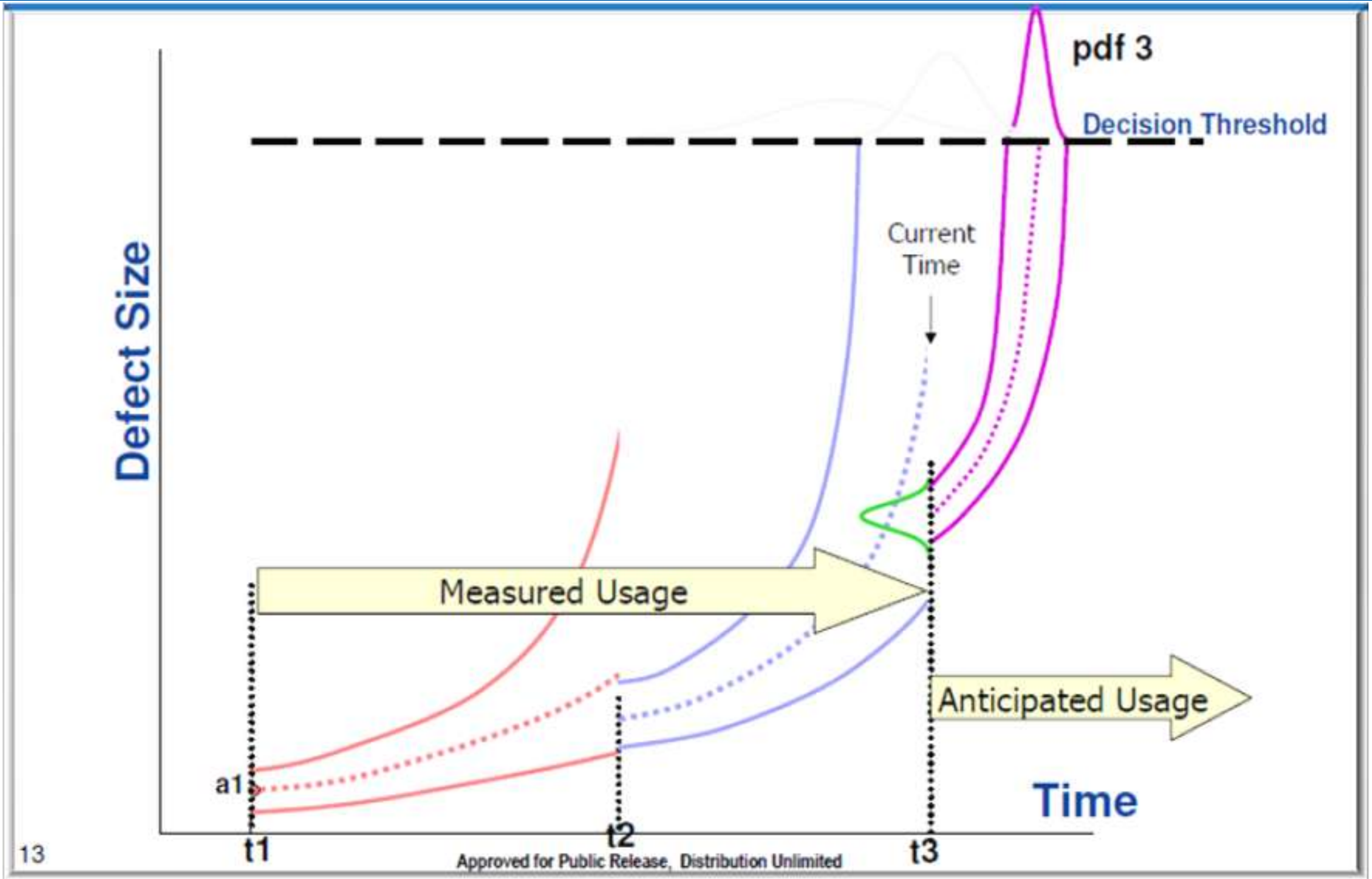
Robert.Silberstein@NGC.com, Stephen.Engel@NGC.com

Initial Prediction Based on Multi-Scale Fatigue Models and Anticipated Usage



Robert.Silberstein@NGC.com, Stephen.Engel@NGC.com

Prediction Updated By Measured Usage & State Awareness Information



Robert.Silberstein@NGC.com, Stephen.Engel@NGC.com

DARPA/NGC Structural Integrity Prognosis System (SIPS)

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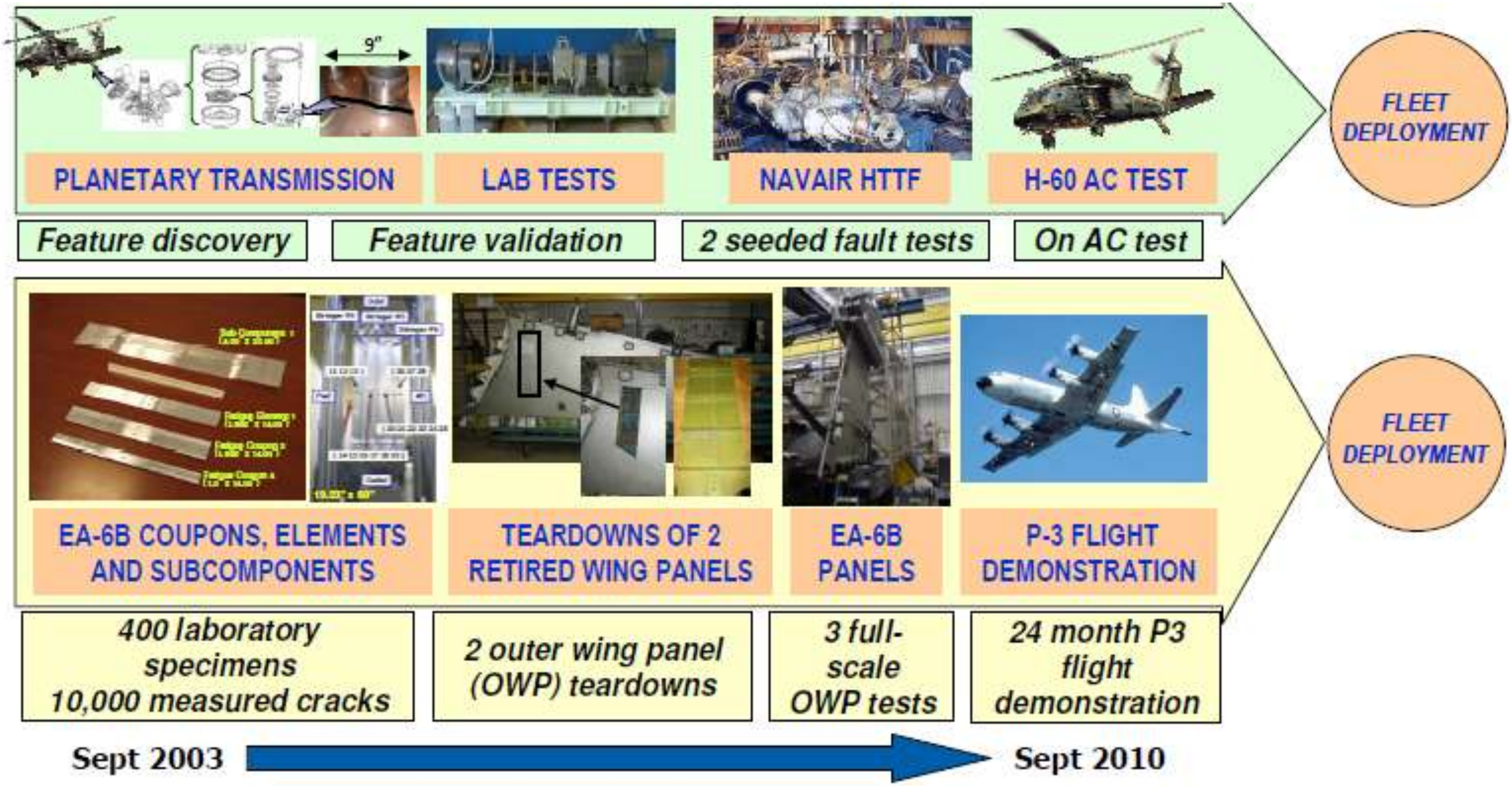


Aero Union Corp, ALCOA, Carnegie Mellon, Cornell, DMI Inc., Impact Technologies, Georgia Tech, JENTEK Inc., Lehigh, Mississippi State, Oceana Systems, Ohio State, Penn State ARL, PSI Inc, Rensselaer Polytechnic, Sikorsky, Ultra Electronics, University of Maryland, University of Pennsylvania, University of Virginia, Washington State

Robert.Silberstein@NGC.com, Stephen.Engel@NGC.com

Novel Ground Sensors: Infrasound

From:

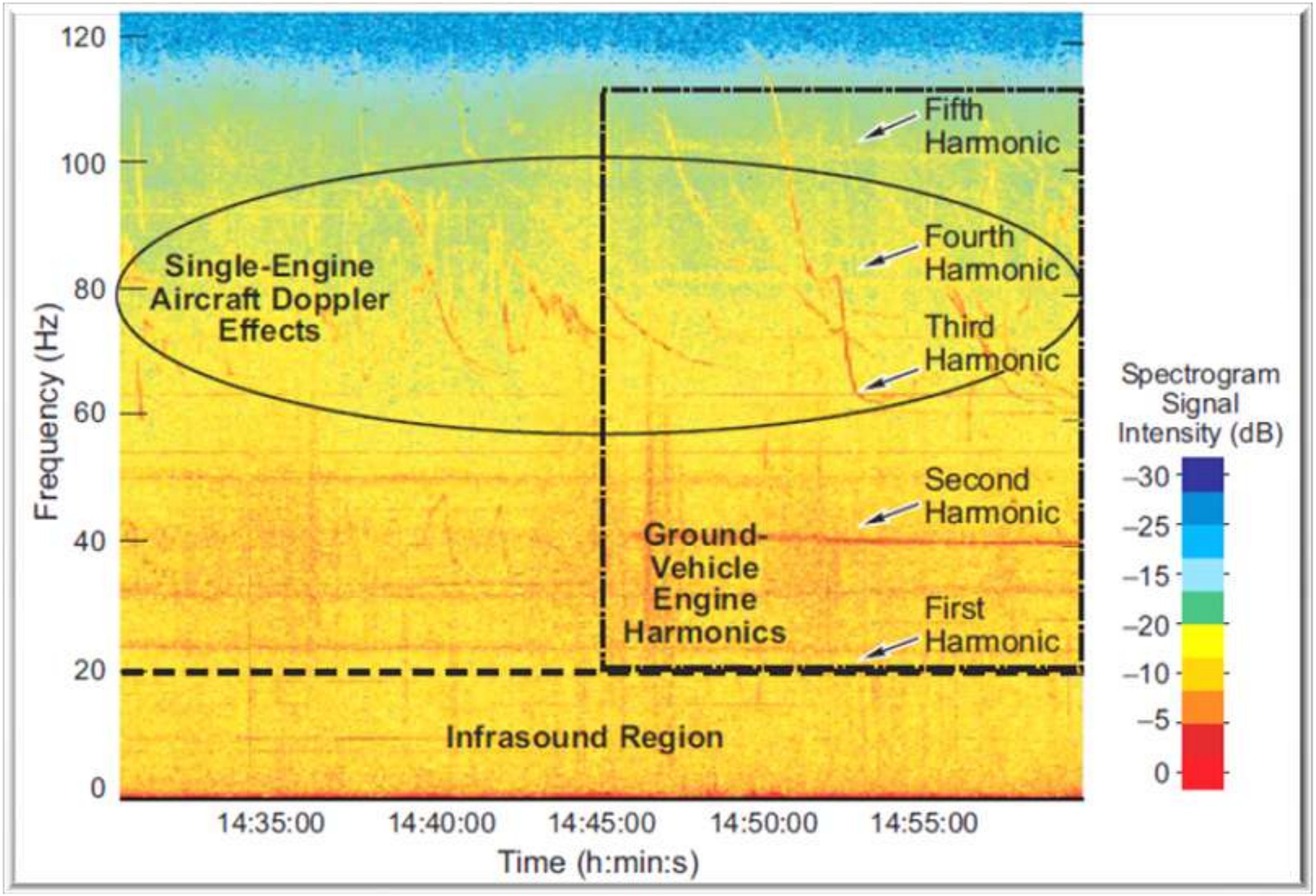
"Infrasound Sensor System Detection of Atlas V Rocket Launch," Northrop Grumman Technology Review Journal, Spring/Summer 2009.

By Eric A. Skowbo*, David C. Muh, and Kelley A. Fanto

Northrop Grumman Aerospace Systems

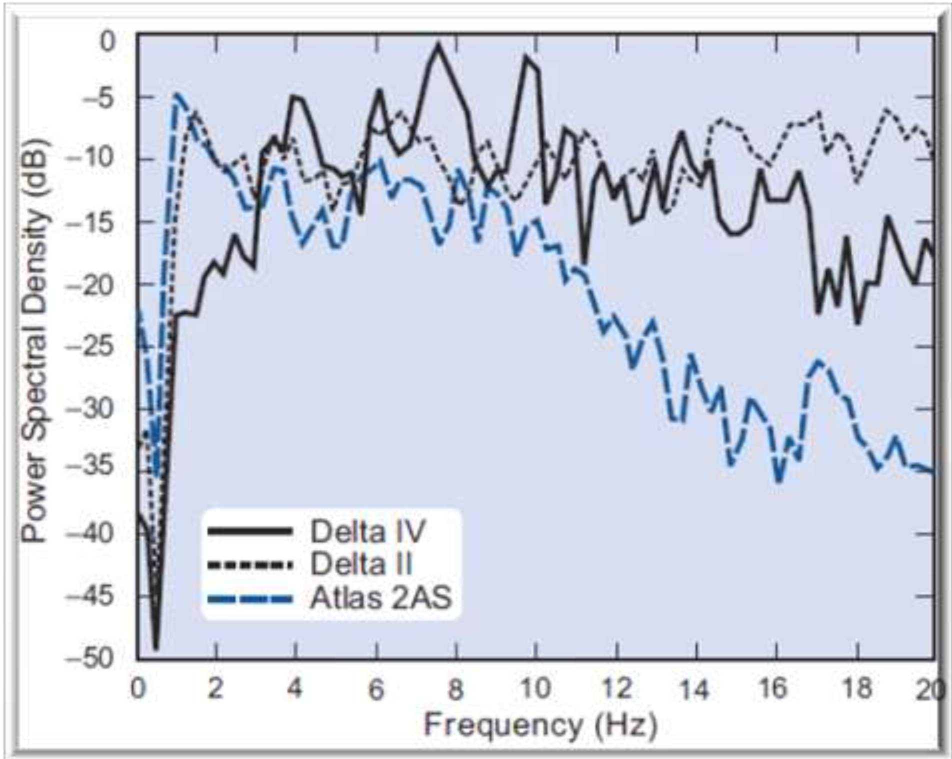
***Eric.Skowbo@NGC.com**

Example Spectrogram of Rural Clutter Effects



Eric.Skowbo@NGC.com

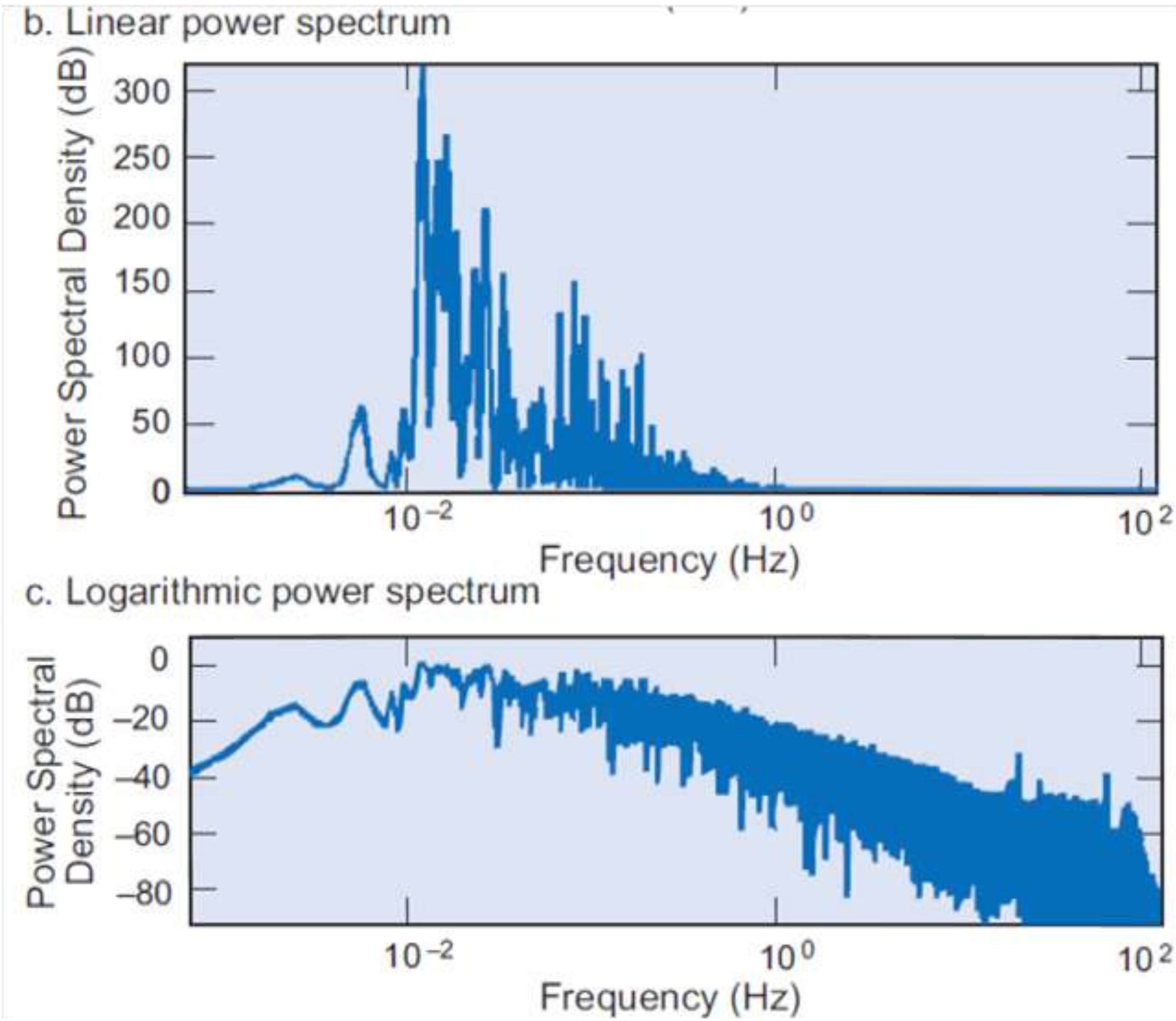
Power Spectral Density of Three Rocket Launches



Atlas V Liftoff

Eric.Skowbo@NGC.com

Signal Processing Results



Eric.Skowbo@NGC.com

Infrasound Propagation – Near and Far Field

Eric.Skowbo@NGC.com

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Emerging Platforms: UAVs

From:

"Vision to Reality," Northrop Grumman's Support to Air Force Unmanned System Vision," Air Force Association Convention, Sept. 2009.

By Michael Isherwood

Northrop Grumman Analysis Center

Mike.Isherwood@NGC.com

Why Unmanned in the Air?

NORTHROP GRUMMAN

Versatile

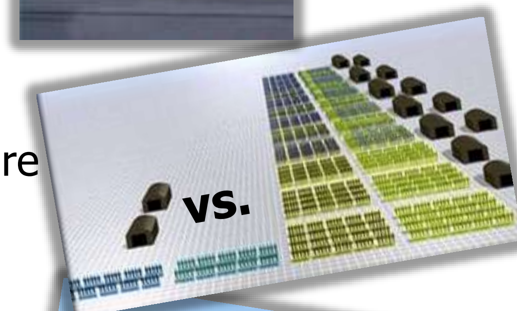
- Unmanned Systems are game changers
- Multi-payload/multi-mission
- Flexible/reconfigurable
- Revolutionary capability / cost

Less Risk

- Reduced Risk to Warfighters
- Insensitivity to Anti-Access / Denial Strategies

Less Cost

- Smaller Force Structure, Smaller Ops / Maintenance / Training Costs



Collaborative

- Integrates / leverages existing force structure
- Operational and Political Advantage

Effective

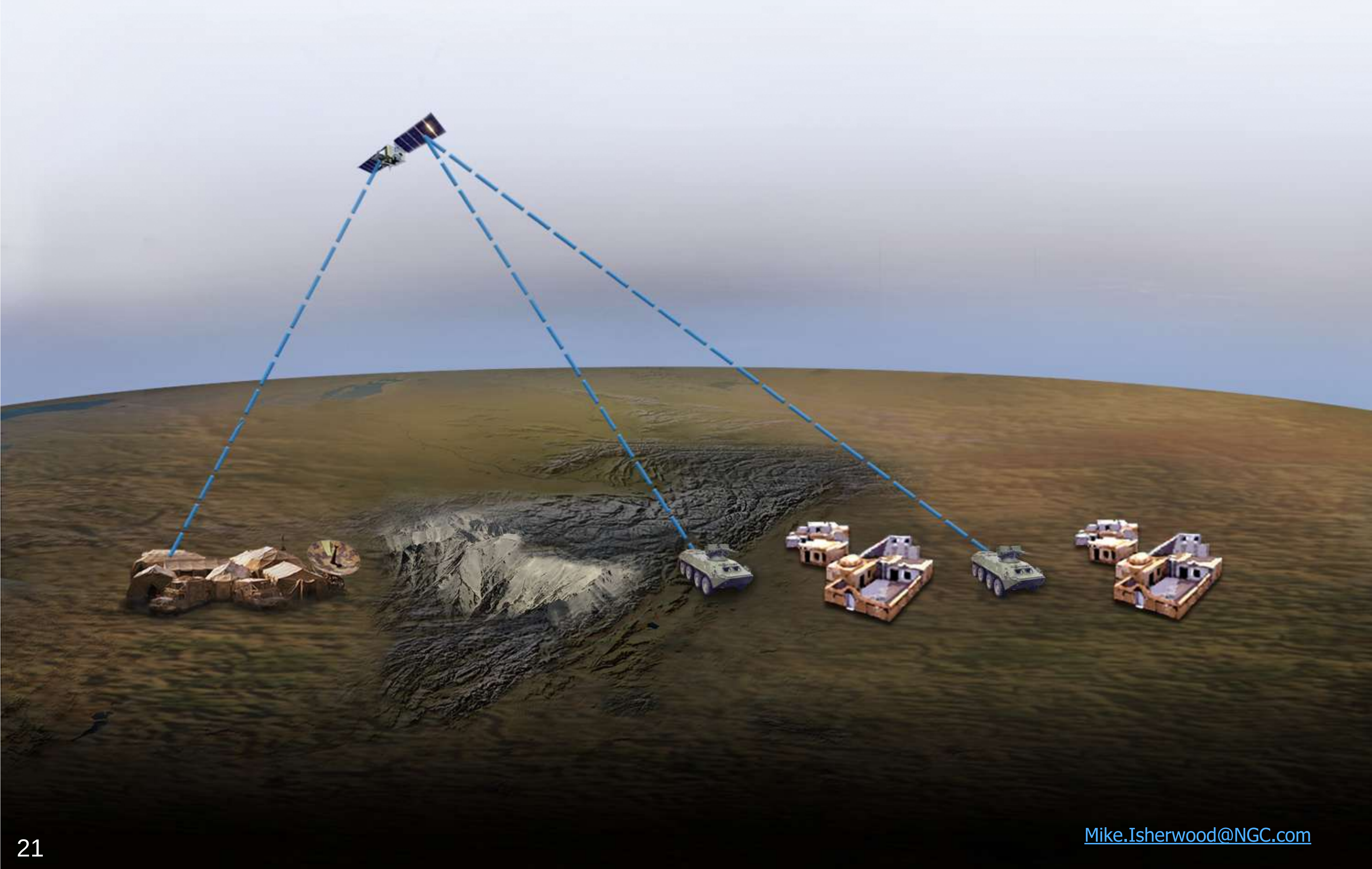
- Greater Endurance
- Greater Survivability
- Addresses Broad Spectrum of Conflict

Efficient

- Unsurpassed Persistence and Autonomy

Mike.Isherwood@NGC.com

Unmanned Air Systems
Increasing Effectiveness of the Joint Team



Mike.Isherwood@NGC.com

Unmanned Air Systems
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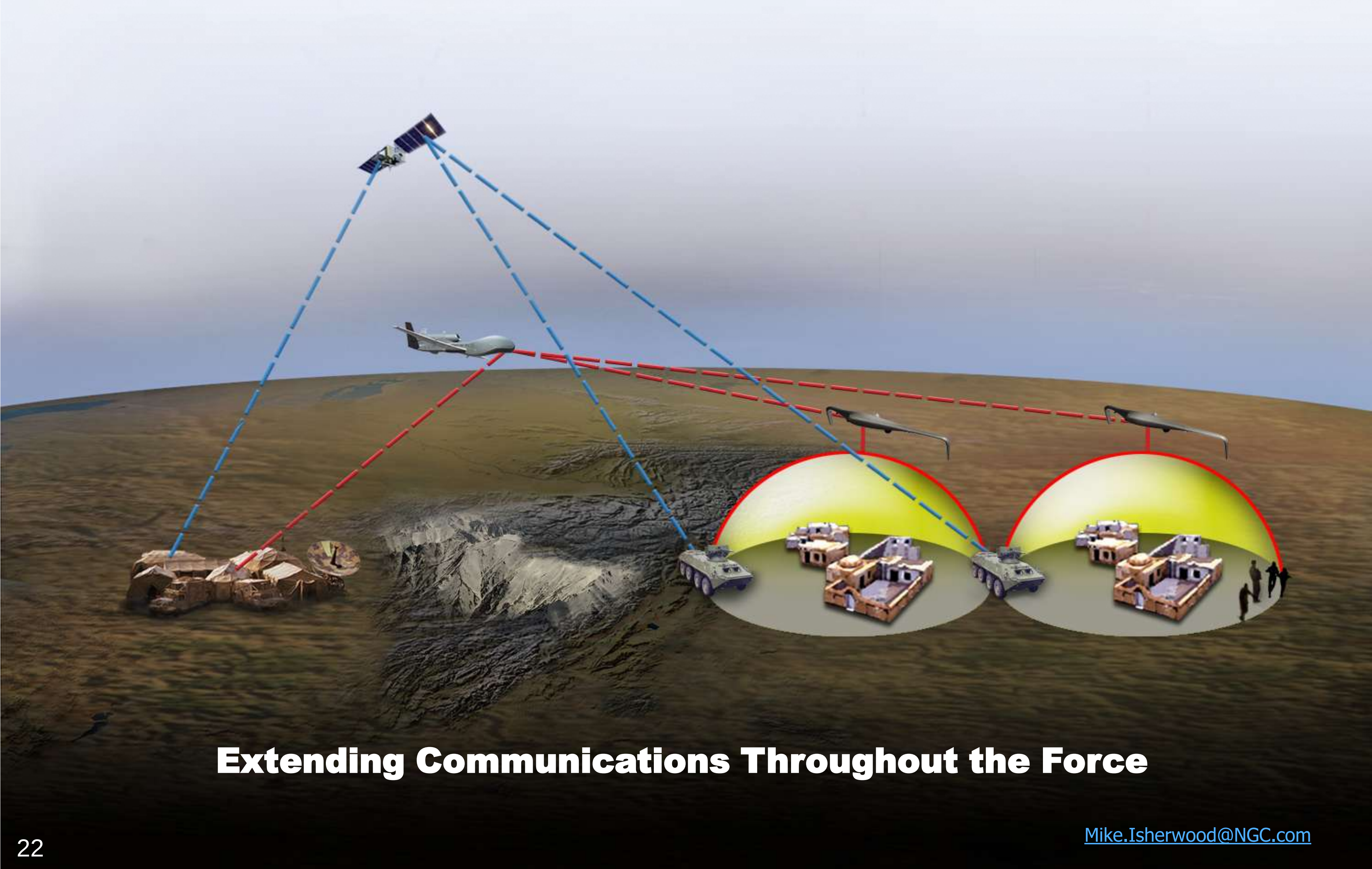

Extending Communications Throughout the Force

Mike.Isherwood@NGC.com

Emerging Opportunities

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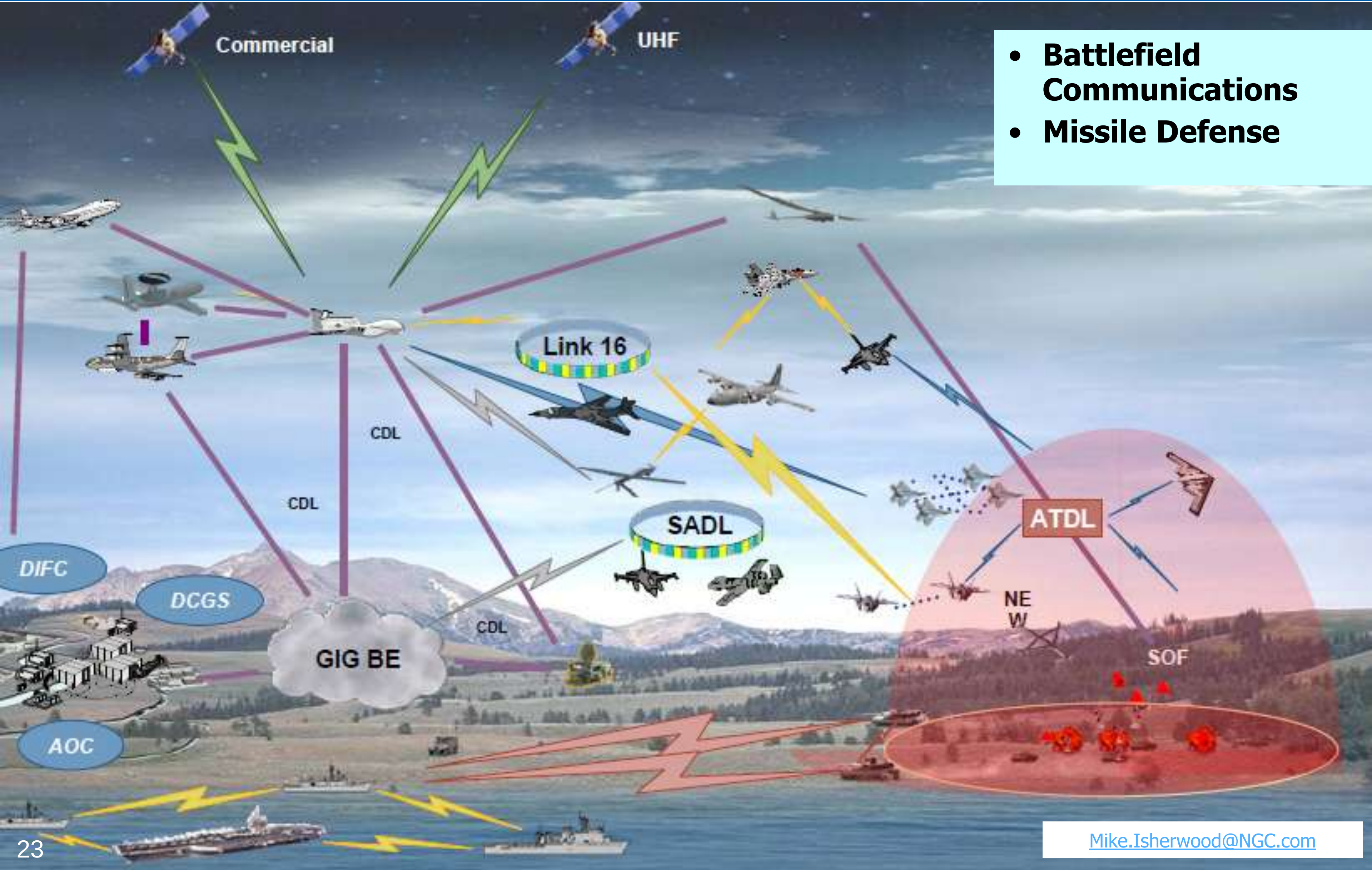
- **Battlefield Communications**
- **Missile Defense**



Mike.Isherwood@NGC.com

Airborne LIDAR

From:

"New Remote Sensing Concepts to Advance Future Mission Capabilities,"

SPIE Conference, San Diego, August 2009.

By Brian K. Baldauf*, Chris Bracikowski, Chung Wong, and Jennifer Logan

Northrop Grumman Aerospace Systems

***Brian.Baldauf@NGC.com**

Instrument Requirements of the Future

Ladar/Lidar, HSI, and Radiometers Cover 80% of Earth Science Missions for This Decade

Mission	Orbit	EO Sensor	RF Sensor	Comment
SMAP NASA	LEO SS		RADAR	JPL in house soil moisture mission
ICESat II NASA	LEO NSS	LIDAR		Ice sheet; QuickICE gap filler from ICESAT
CLARREO NASA/NOAA	LEO Pre	Spectro/Radiometer		Absolute spectrally resolved .4 – 100 μm
DESDynI NASA	LEO SS	LIDAR	RADAR	Deformation, Ecosystem Structure and Ice
HyspIRI NASA	LEO SS	Spectro/Radiometer		Land surface .4 – 2.5 μm
ASCENDS NASA	LEO SS	LIDAR		Multi freq for CO2
SWOT NASA	LEO SS		RADARs	Ka, C for ocean, lake, river water levels
GEO-CAPE NASA	GEO	Spectro/Radiometer		Atmo gas, ocean color
ACE NASA	LEO SS	LIDAR	Doppler RADAR	Aerosols and clouds ocean color biochem
LIST NASA	LEO SS	LIDAR		Land surface for landslides, water runoff
PATH NASA	GEO		MMW Spectro	Temp and Moisture soundings
GRACE-II NAA	LEO SS	LIDAR or	μwave	Gravity fields for large-scale water movement
SCLP NASA	LEO SS	Spectro/Radiometer	RADARs	K, Ka / Ku, X bands
GACM NASA	LEO SS	Spectro/Radiometer	μwave limb sounder	O3 transport
3D-Winds Demo NASA	LEO SS	LIDAR		Tropo winds

Lidar Mission

HSI and/or Radiometer Mission

Current initiatives

Brian.Baldauf@NGC.com

LADAR Capabilities at NGAS

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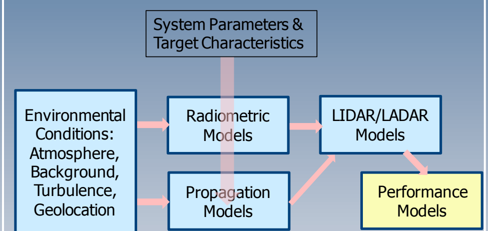
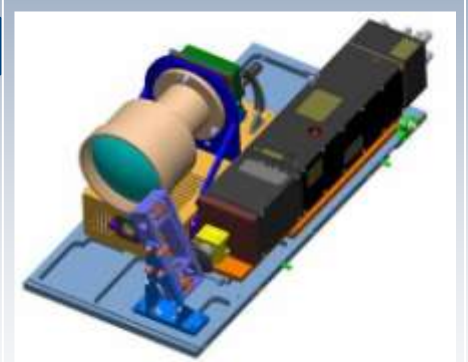
Modeling & Phenomenology



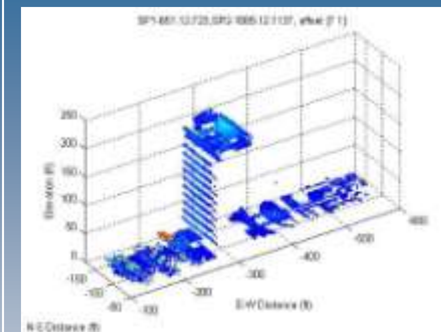
- LxDAR Code Set
- Matlab based tool kit

Hardware Design & Build

- ASC Flash 3D Camera
- Eye-safe 1550 nm laser
- 3 Flight Campaigns in 2008



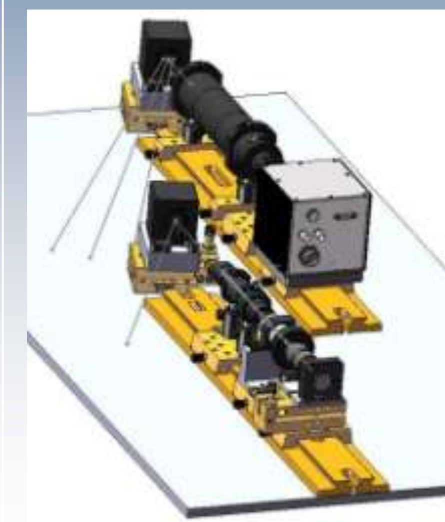
Data Processing



- Geometric Corrections
- In-Track and Cross-Track Stitching
- Geolocation

Future LADAR Missions

- Single Photon Systems
- Scanning System for higher coverage rate
- Higher Altitude



<u>LADAR research engineering team members:</u>

Jamie Barter	Christopher Bracikowski	William Cottingame
Miguel Figueroa	Donald Henderson	Jennifer Logan
Ravi Narasimhan	Susan Rico	Barry Stark
Michael Waterman	Chung M. Wong	

Brian.Baldauf@NGC.com

Current Airborne 3D Flash Ladar System

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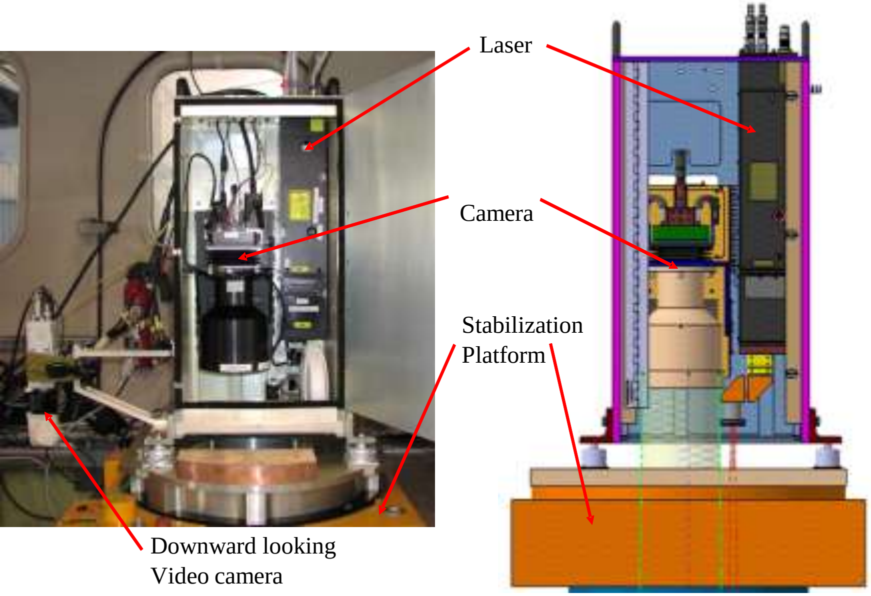
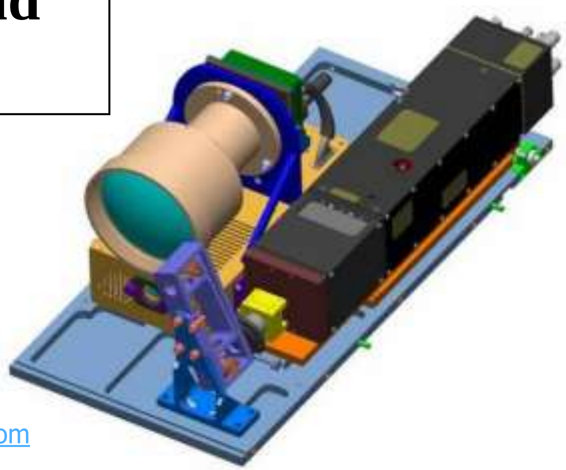
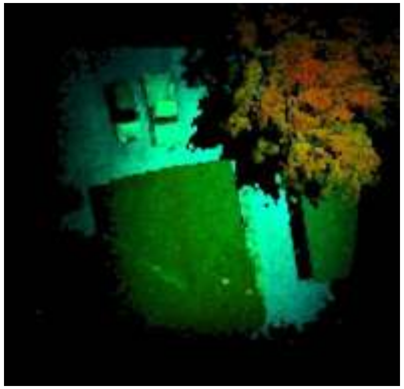


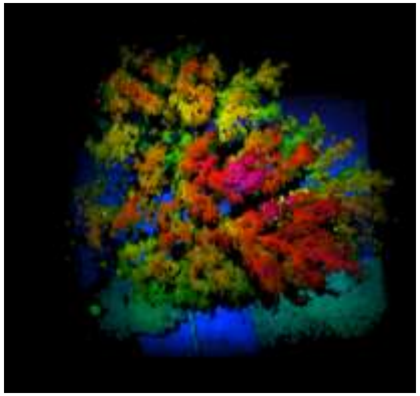
Nd:YAG laser

laser	flashlamp pumped Nd:YAG	
wavelength	1.57micron	
pulse energy	50mJ	
pulse width (FWHM)	6.7ns	
pulse rate	30Hz	
FPA	InGaAs APD	
FPA size	128 x 128 pixels	
pixel pitch	100micron	
time slices/pixel/frame	20	
time per slice	2.2ns	
collector lens	500mmF, 120mm dia	
Camera FOV	1.47deg	
GSD (7000 ft / 2134 m)	43 cm	
altitude test range	3,000 - 10,000ft (914 - 3048m)	
illumination angle	1 deg	1.5 deg
spot @ 7,000ft (2134m)	37m	54m
# of pixels illuminated	87 x 87	128 x 128

Built, tested and flown





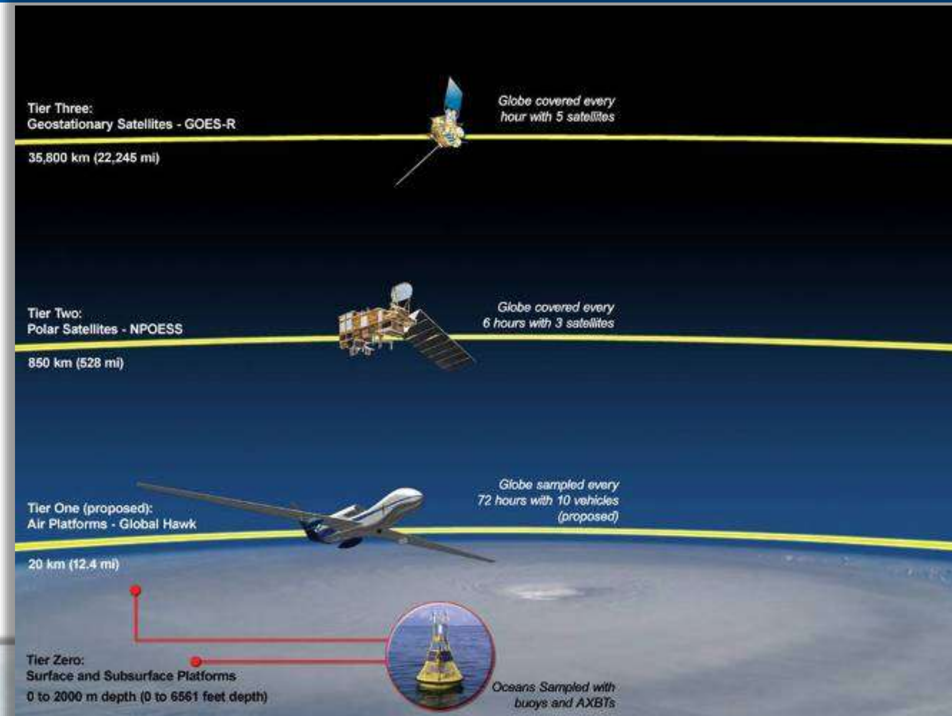


Brian.Baldauf@NGC.com

Developing Future Instrument Capabilities for NASA Global Hawk

NORTHROP GRUMMAN

- NASA's latest airborne platform
- Bridges the Gap between space and earth based sensors
- Can simultaneously support numerous instruments such as LIDAR systems
- Collection of data in remote and inaccessible locations
- Developing concepts for integrated HIS and LIDAR systems
  - 1000-1500 lb payload capacity
  - 11000 nm range
  - 65kft alt
  - 343 knots TAS
  - 30+ hour endurance
- Three ACTD aircraft transferred from USAF to NASA
- Aircraft Based at NASA Dryden, Edwards Air Force Base, CA



Brian.Baldauf@NGC.com

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Air & Space
Remote Sensing

From:

"The Hyperspectral Airborne Tactical Instrument (HATI): a Low-cost Compact Airborne Hyperspectral Imager,"

SPIE Conference, San Diego, August 2009.

By Stephanie Sandor-Leahy*, Brian Baldauf, Mark Hemlinger, Miguel Figueroa, Sveinn Thordarson

Northrop Grumman Aerospace Systems

*Stephanie.Sandor-Leahy@NGC.com

NGAS Sensor Products & Technologies

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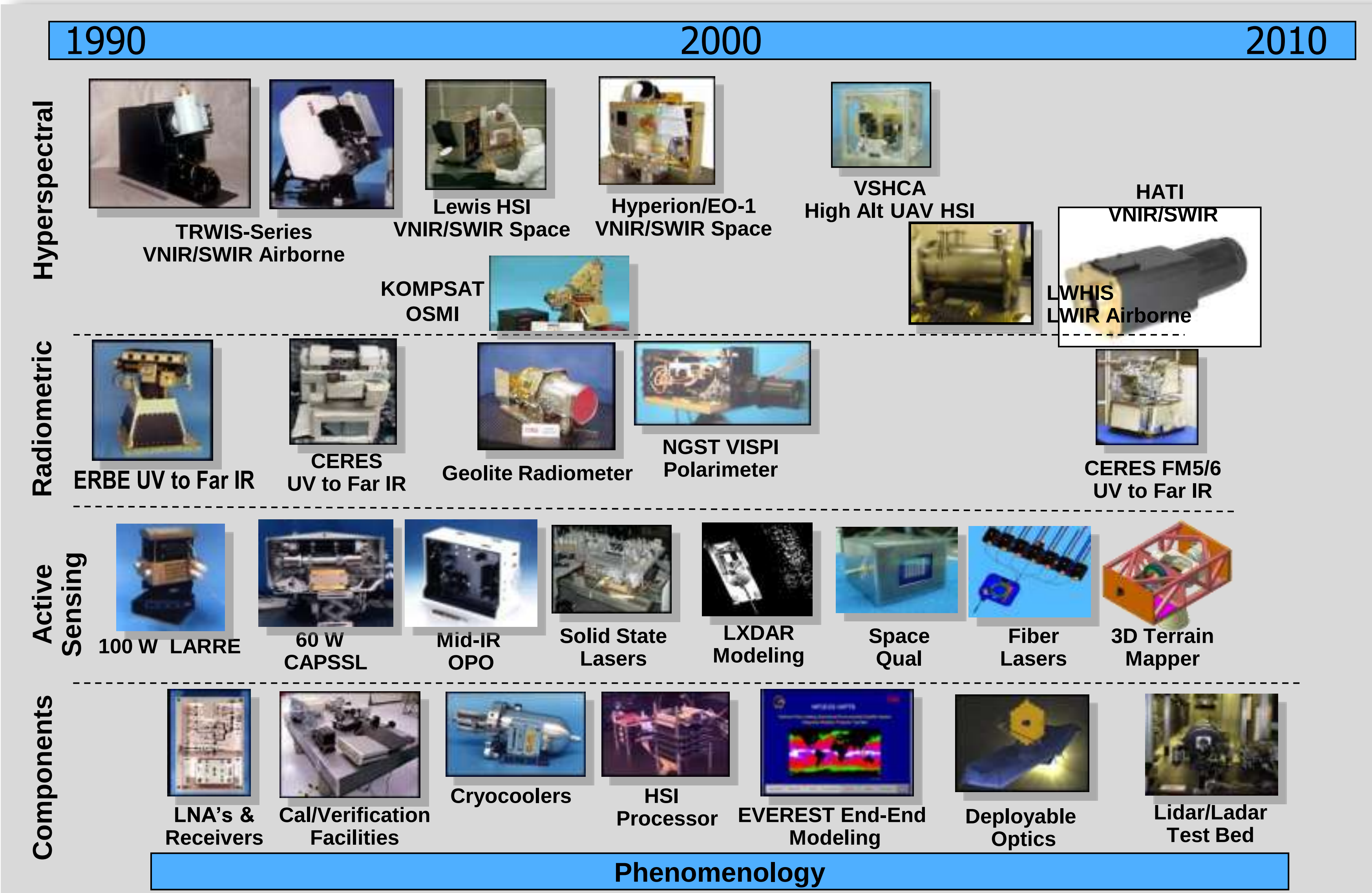


Stephanie.Sandor-Leahy@NGC.com

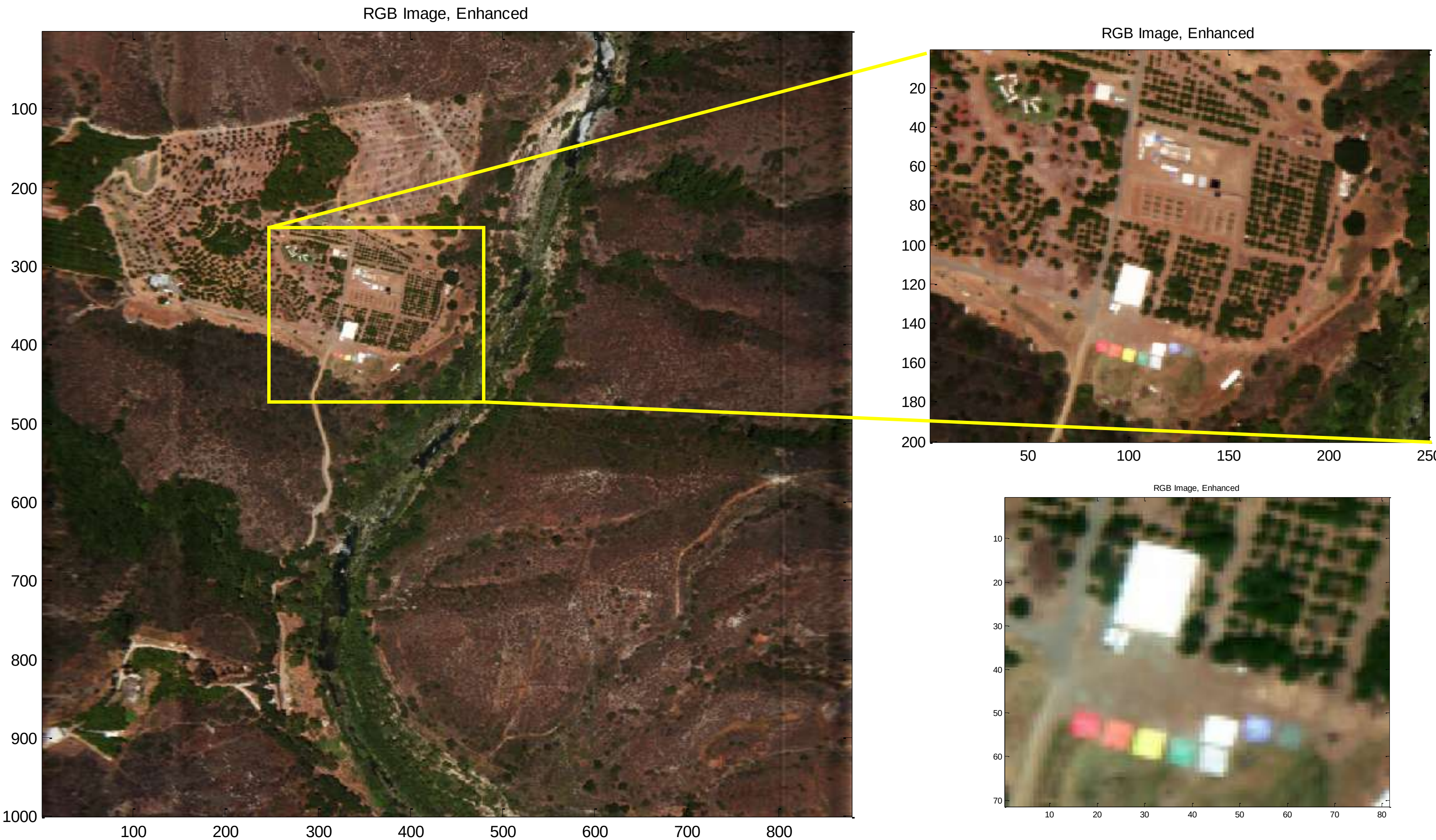
Hyperspectral Airborne Tactical Instrument (HATI) Overview

- Multiple airborne campaign and data collects, 2007/2008
- Compact airborne hyperspectral imager designed to fly on a variety of platforms and to be integrated with other sensors in NGAS's instrument suite
  - NGAS Long Wave Hyperspectral Imaging Spectrometer (LWHIS)
  - NGAS 3D flash LADAR system
- Push broom sensor gathers information in the 400 nm to 1700 nm wavelength range
- Mounted on COTS aerial photography stabilization platform
- Wide variety of earth observing missions:
  - Geological/natural resource surveying, vegetation (re-growth, invasive species,…)
  - Forestry, urban, ocean color, HABs
- Future initiatives: upgrades to expand the short wave infrared (SWIR) range and capabilities to facilitate near-autonomous high-altitude operation

Piper Navajo

Stephanie.Sandor-Leahy@NGC.com

Sample HATI Data over Calibration Site – June 2008



60 Hz (~1m GSD) High Resolution HATI Image Over Santa Margarita Ecological Reserve Calibration Site

Stephanie.Sandor-Leahy@NGC.com

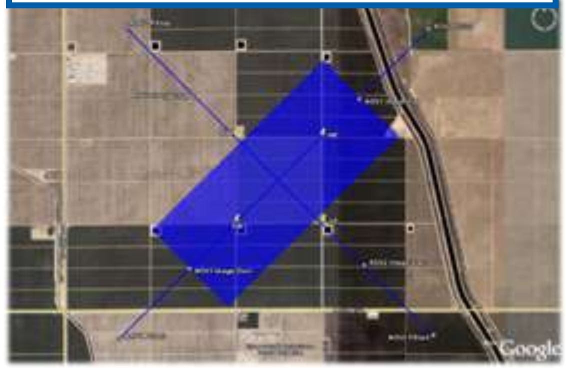
Mark Helmlinger (NGAS) with field spectrometer and Lee Johnson (NASA Ames) document the lush growth along the Santa Margarita River (ground verification)

Stephanie.Sandor-Leahy@NGC.com

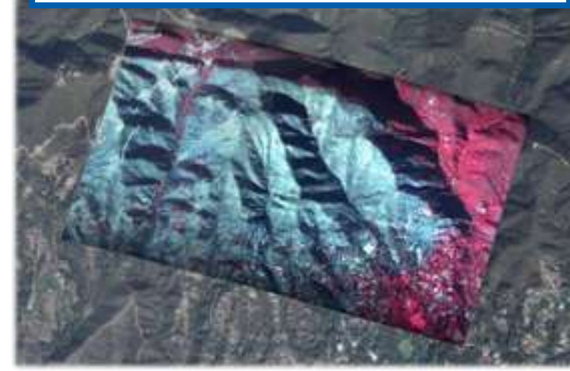
Project Overview

Jasper Ridge Biological Preserve, - hyperspectral & Ladar

Orchard, - hyperspectral & Ladar



Montecito Fire, - hyperspectral



- 2008 - November hyperspectral and Ladar data collection
  - Rapid 2008 execution - 2 month modification, second HSI camera added, integration and collect
  - Several hundred Gbytes of data acquired
  - substantial ground truth data collected at each site
- 2009 - Data Processing for calibration and orthorectification, and data fusion

Urban area in San Mateo County, - hyperspectral & Ladar

San Francisco and Monterey Bay, - hyperspectral

Stephanie.Sandor-Leahy@NGC.com

Future Plans: Integrating HATI on NASA Global Hawk

- Two ACTD aircraft transferred from USAF
- Aircraft Based at NASA Dryden, Edwards AFB CA
- Equal Partnership with Northrop Grumman shared expenses and operations
- First flight planned in August 2009
- New Plug-and-Play Payload Interfaces

- 116 ft wingspan
- 1500 lb payload capacity
- 11000 nm range
- 65kft alt

- 343 knots TAS
- 30+ hour endurance
- 700 lbs per side POD payload

Stephanie.Sandor-Leahy@NGC.com

NORTHROP GRUMMAN

Sensor Systems for Homeland Security

From:

"Impact of Nanotechnology"

And

"Homeland Security, Defense and Northrop Grumman"

By Dr.Ronald G. Pirich

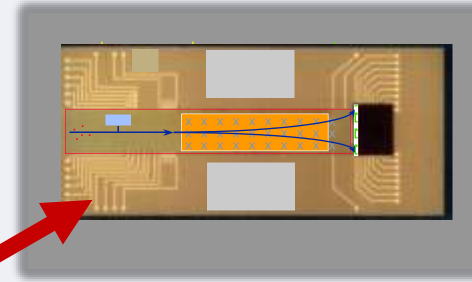
Northrop Grumman Aerospace Systems

Ron.Pirich@NGC.com

Chemical & Biological Sensor Detection Systems and Technologies

Passive Standoff Chemical Detection

Automated Bio Detector



Next-Generation Miniature Chem/Bio Sensor

Computer Aided Dispatch for Emergency Response

Mobile Chem/Bio Detection

Radar Detection of Suspicious Release

Sensor Fusion and Target Recognition

Ron.Pirich@NGC.com

WMD Sensor Detection & Prediction – Northrop Grumman & University Collaboration

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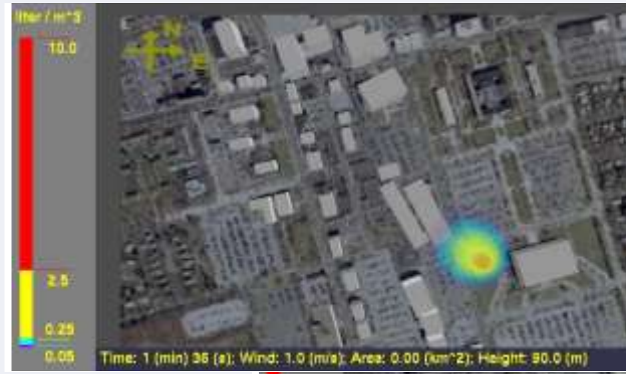
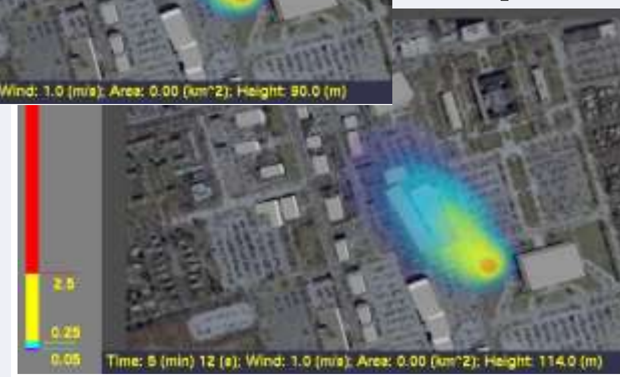
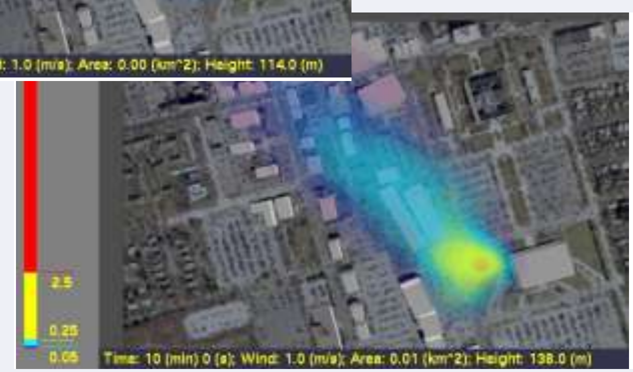


Stony Brook University's LBM Model Uses MCAD Source Term & Meteorological Conditions to Accurately Predict Plume's Evolution (Concentration, Areas Affected)



Northrop Grumman's MCAD Detects Chemical Agent Concentration & Spatial Extent (MCAD Source Term)



Ron.Pirich@NGC.com

Intelligent Synthesized Sensor & Network Systems Integration

Urban Environment:
- Complex
- Varied
- Threat Dissemination Will Depend on Threat, Location, Time of Day/Month

Must Determine Intelligent Combination of Sensor Types, Fixed Vs. Mobile and Make Use of Existing Infrastructure (Police & Emergency Vehicles, Communications)

Synthesized HLS Systems:
- Meteorological, C, B, N, R, E/O
- Stand-off, Remote
- Fixed, Mobile, Airborne

What combination gives adequate coverage yet is affordable

Ron.Pirich@NGC.com

NORTHROP GRUMMAN

Future Technologies: Wireless Power

From:

"Northrop Grumman Technology Development - Overview,"

Livingston Nanotechnology Conference, Dec. 2008

By Leonard Poveromo

Northrop Grumman Aerospace Systems

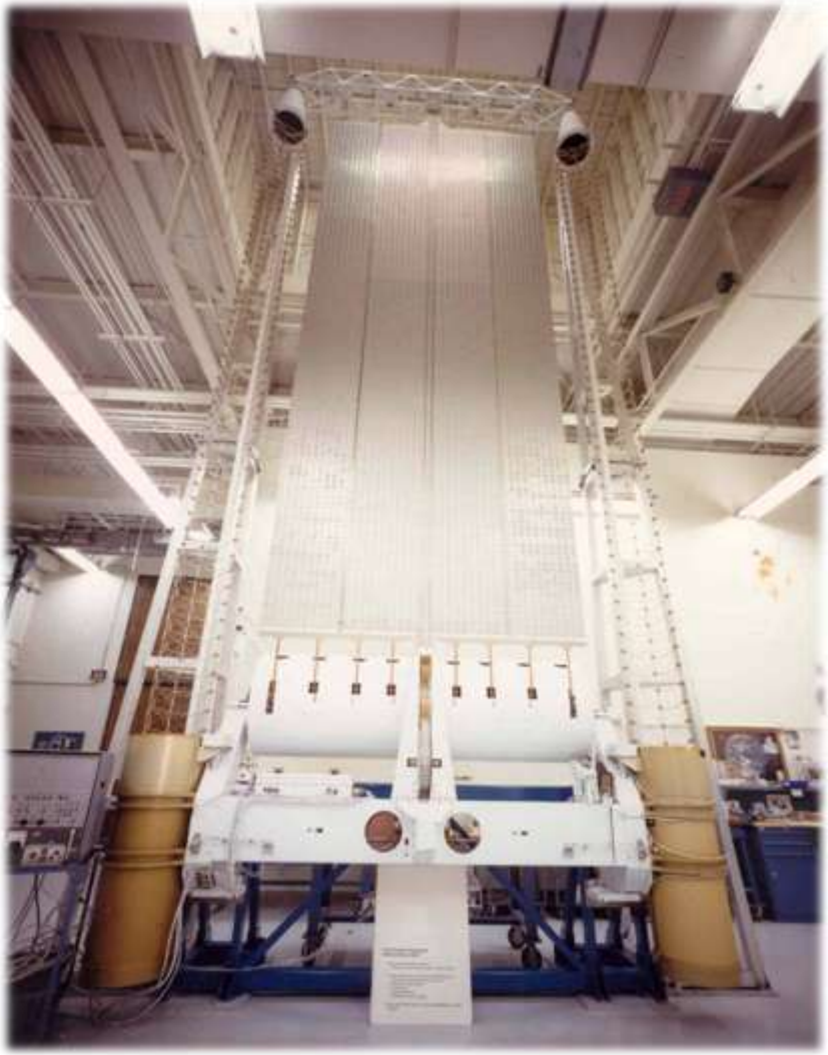
Leonard.Poveromo@NGC.com

Wireless Power Applications

- Ground Applications
  - Military bases – power/communication to remote sites
  - Temporary ship-to-shore power/communication
  - Temporary power grid infrastructure
  - Temporary communications (populated with comm. modules)
  - Temporary power generation (populated with flexible solar cells)
  - Emergency response/humanitarian operations
  - Park Service /Dept of Interior
- Space Applications
  - Space debris/attack protection
  - Satellite to satellite power transmission
  - Individual space power system
  - Lunar site-to-site power transmission

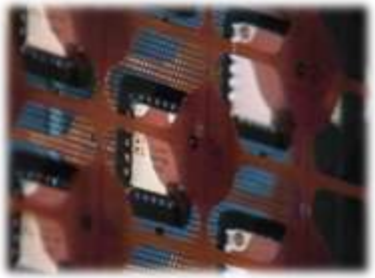
Leonard.Poveromo@NGC.com

History: Space-Based Radar, Roller Shade Array

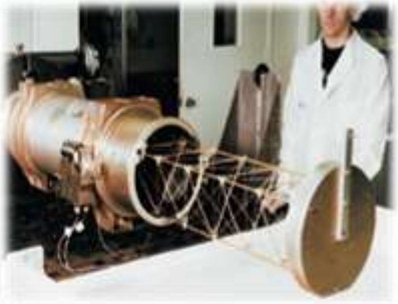


Pictures of the 8‘x20' Grumman roller shade microwave lens assembly in test. It was being prepared for flight before the Challenger shuttle loss caused a cancellation.
New development would create modular transmitter version to tile a large structure.

Transmit / Receive Modules with Individual T/R Antennas



Reversible Mast Assembly



Leonard.Poveromo@NGC.com

Individual Space Power System (ISPS)

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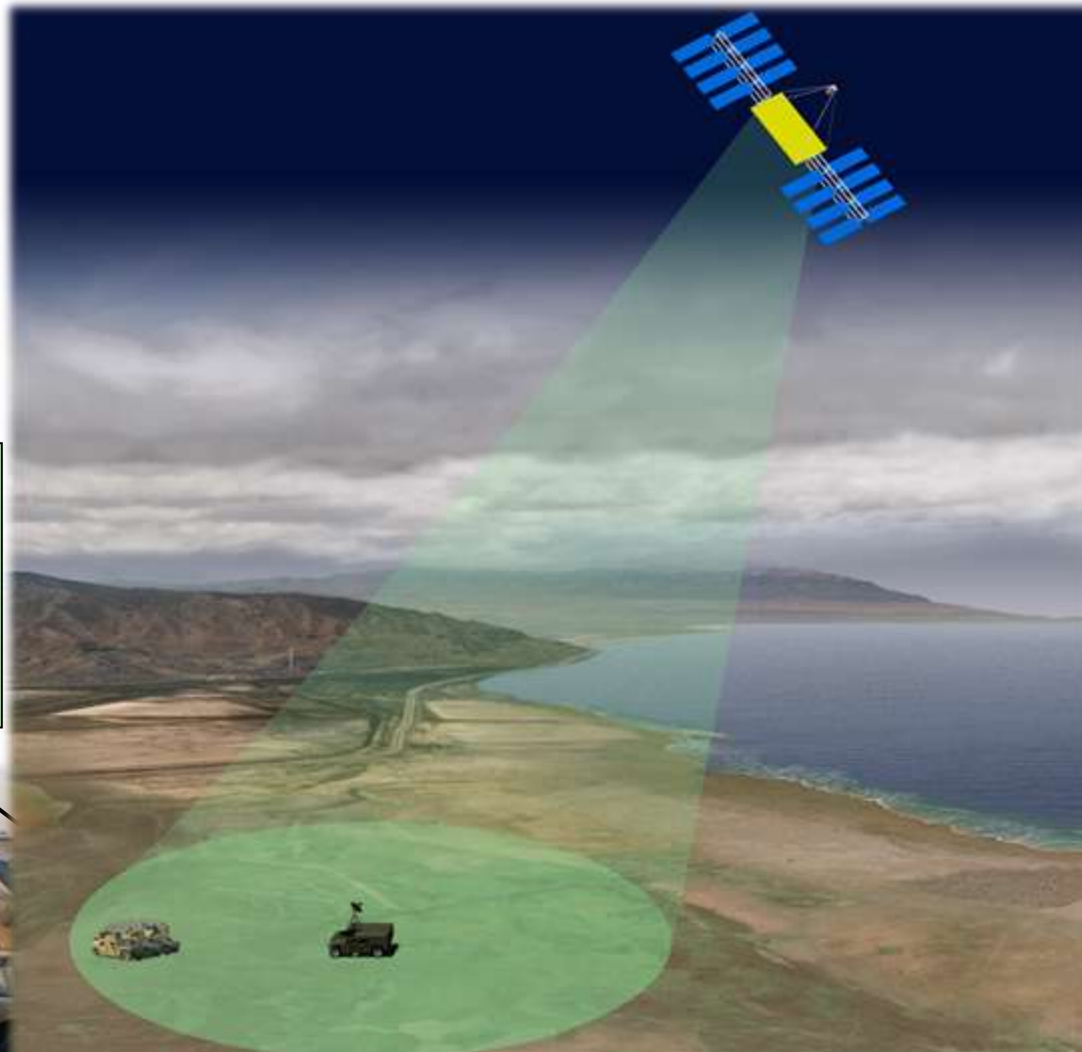
- Less vulnerable to attack
- Safe, renewable power
- 1/16 cell phone exposure
- Economically justifiable to DoD
- Reduces logistics tail
- Humanitarian/commercial apps
- Demo area expandable globally

Fabric Embedded Rectennas
Scalable
Initial 0.1 Watt to single soldier
Initial 3.6 MegaWatt to power a brigade
All Weather Power
Day or Night
Can Follow Troop Movements



Low Power Beam
Control Transmitter

Leonard.Poveromo@NGC.com

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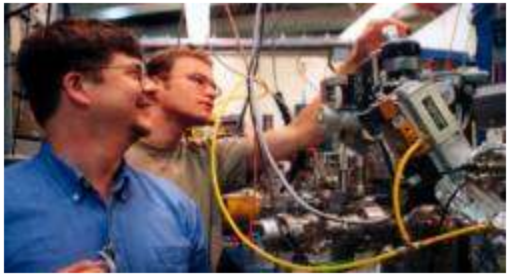
Conclusions

What’s Next in Technology?

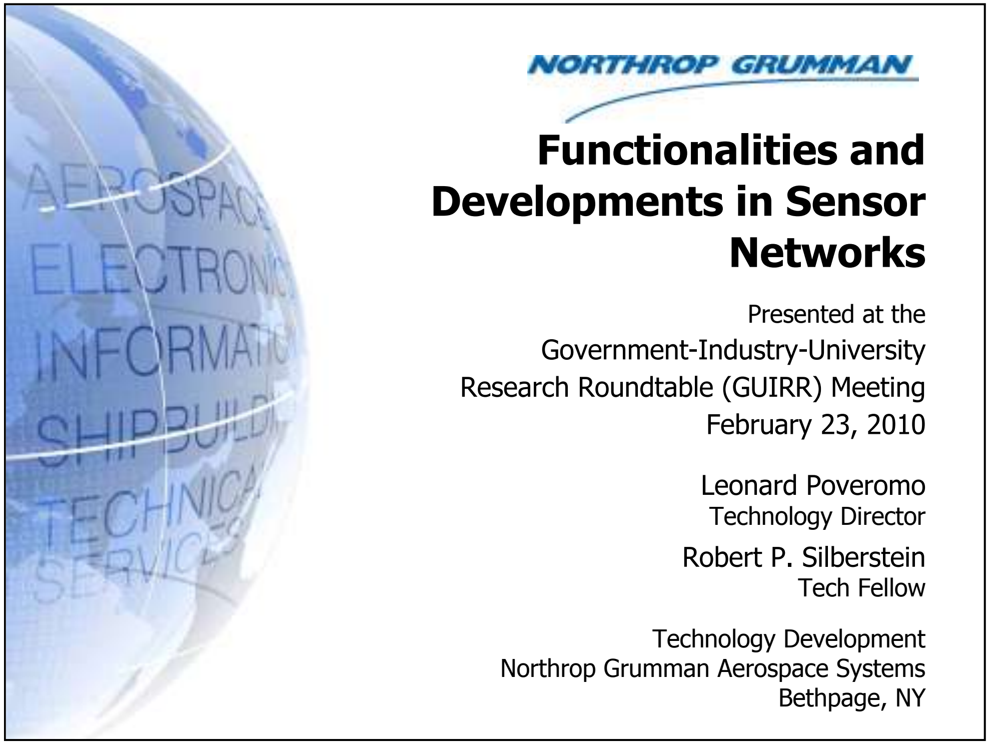
- 18th and 19th century chemistry gave us the energetic materials of World War I
- 19th and 20th century physics gave us nuclear weapons
- What happens when 21st century computing power, “bio,” “nano,” and photonics converge?
- Will adversaries weaponize...?
  - Virological and bacteriological systems
  - Ground-based directed energy
  - Space disruption
  - Electromagnetic (rail guns, pulse)
  - Unbreakable encryption
  - Energy strategies

Technology Collaborations / Lessons Learned



- Customers
  - Identify key customers whose technology roadmaps align with NGAS strategic technologies for CRAD collaboration
  - DARPA, ONR, AFRL, NIMA, Lincoln Labs, Classified
- Sectors
  - Identify strategic mutual interests for technology collaboration via cross sector exchanges, NGC Technology database
  - All Northrop Grumman sectors
- Suppliers
  - Identify key suppliers with unique developed products/capabilities or subject matter experts
- Universities/Laboratories
  - Identify key universities/laboratories pursuing 6.1, 6.2 in unique technology areas

Questions?



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Leonard Poveromo
Technology Director
Leonard.Poveromo@NGC.com

Robert P. Silberstein
Tech Fellow
Robert.Silberstein@NGC.com

Northrop Grumman Aerospace Systems
Bethpage, NY

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