Boeing Technology

9th Annual Science & Engineering Technology Conference /
DoD Tech Exposition

Boeing's Approach to Innovation & Technology Integration

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The Boeing Company

April 16, 2008

The Boeing Company Today

Boeing Commercial Airplanes

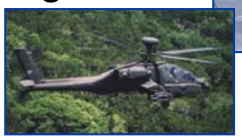
Integrated Defense Systems

Customers Demanding Connected, Integrated and Intelligent System of Systems

Today


Fighters


Transport


Helicopters


Communication


Surveillance


Bombers


Weapons

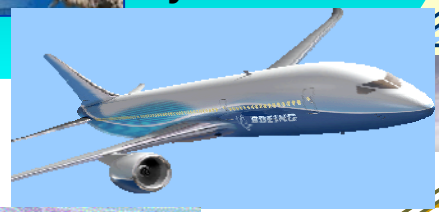

Command Control


Launch

Transformation Programs


Future Combat System


Network Communications System

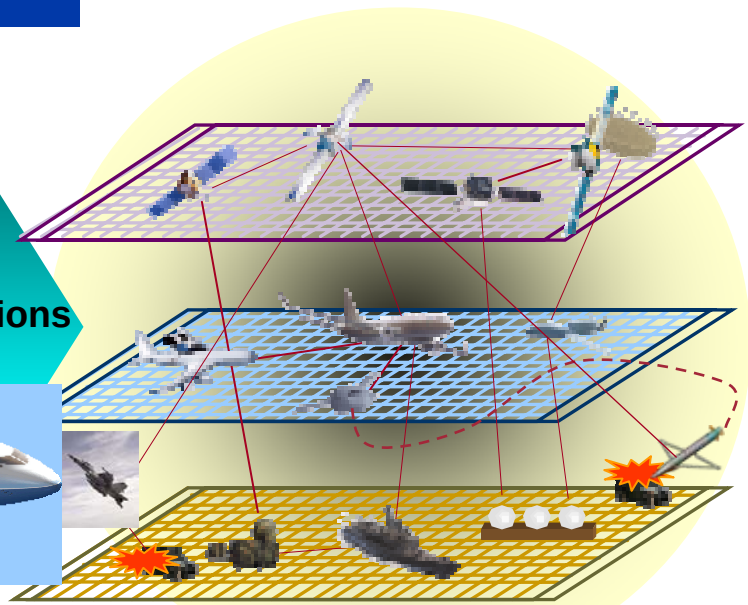



Traffic


Flight

Air Management

Tomorrow



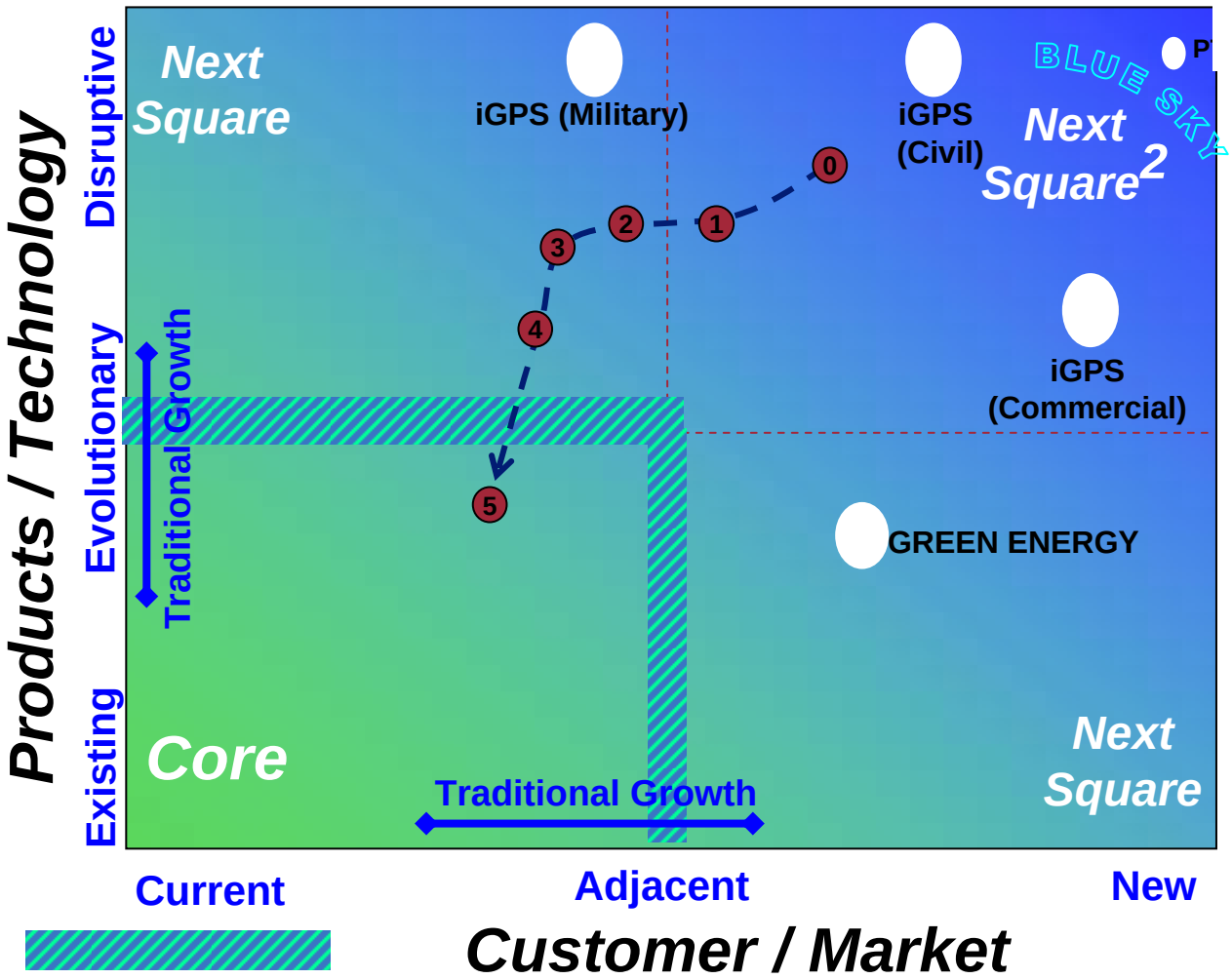
Ad hoc network of highly adaptable systems

Boeing is balancing a customer pull for integrated systems with technology push for "Innovation"

Innovation Strategy

- **Leverage Boeing technology to find & develop growth platforms:**
  - Markets & businesses that meet Boeing criteria
- **Create competitive advantage in new markets and businesses**
  - Leverage Boeing's differentiated assets
  - Focus on Breakthrough Technology
  - Create new verticals via development/acquire
- **Leverage outside R&D resources (DARPA, military labs, universities,…)**
- **Efficient Stage/Gate Innovation Process**
  - Migrating growth opportunities to comfort zone

Strategy for Technology Integration – Spiral to Core



The Key was to move FCS toward the core by:

- ✓ **Partnering**
  - 1 *Experimentation & Customer Feedback*
  - 2 *Teamed with SAIC*
    - *Army Land Combat domain knowledge*
  - 3 *Army LSI for FCS*
    - *UDLP & GD added*
- ✓ **Spiral Development**
  - 4 *Phased Technology Increments*
- ✓ **Spiral Out**
  - 5 *To Current Force*

Technology Integration Driven by Customer Requirements (Pull) and Innovation (Push)

Understand Customers Most Important & Deficient Capability Needs

Spin-off to Adjacent Markets (Next Square^2)

Develop Market-Driving Growth Strategies

Identify Capability Needs & IP Considerations

Capability Gap

Capability Currently Available

Identify Technology Needs
(Technology, processes, skills)

Competitor Analysis

State of the Art Analysis*

Technology Sources

- Phantom Works
- IDS Businesses
- Strategic Partners
- Suppliers
- CRAD
- Government Labs
- Strategic Universities

Prioritize & Allocate Investments

Develop, Integrate & Protect Technologies

Transition and Insert Technically Superior Solutions For Achieving Growth And Productivity

Growth

Customer Satisfaction

Productivity

**** - Technology Watch and Disruptive Technologies - STFs***

21st Century Defense Technology Vectors

Key Vectors	Boeing Perspective: Products / Development / Research / Ideas	Imperatives
Precision Sensing, Navigation & Timing	ICBM-IMU, GPS-IIF, GPS-III, Very Small SDB, JDAM, SDB, GMD, iGPS (Comm & Nav)	10 x improvement, Integrate Comms & Navigation
Integrated C4ISR	FCS SOSCOE, EP-X, Un-blinking Eye, P-8A, TSAT, Foliage Penetration	No Stovepipes between ISR Systems Ad-Hoc Task/Exploit
Info Assurance	EA-18G, JTRS, High Integrity Knowledge Mgmt, Railhead, Secure Network Server (SNS)	High Integrity Networks & Computer Systems
Nano-electronics & Nano Technology	G-bytes/sec Analog-Digital, RF & Digital Systems on Chip, ASIC Processors, Mission Specific Processors, Carbon-X	Intelligence at the edge, 20 yrs till Silicon = Human
Laser & Photonics	ABL, Laser Comms, ATL, Solid State HE Lasers	Communicate, Tag and Engage at the Speed of Light
Unmanned Systems & Robotics	ScanEagle, FCS Robotics, Variably Manned Systems, A-160, Orbital Express	High Integrity Zero "Pilot" Operations
Energy & Environment	Space Solar Cells, Bio-Fuels, Terrestrial Solar Cells, BWB, H^2 Powered UAVs	High Efficiency, Zero Emissions, Alternate Energy

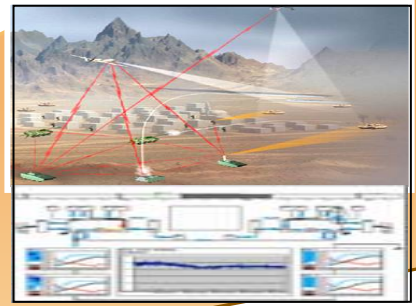
Successful Technology Integration Requires M&S, Experimentation, and Rapid Prototyping

- Build a Little
- Test a Little
- Think a Lot

Lessons Learned

Rapid Prototyping

Experimentation



Modeling & Simulation

Conceptual Idea

Key Components for Successful Technology Integration

Modeling & Simulation Environment

Virtual Warfighter integrates Boeing LABNET infrastructure with JEFX infrastructure enabling additional virtual assets as well as enhanced M&S and assessment capabilities in JEFX2006.

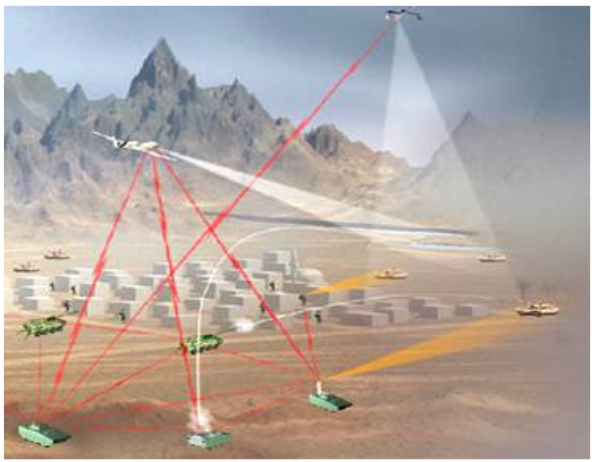
Virtual Assets to be used during JEFX2006 events

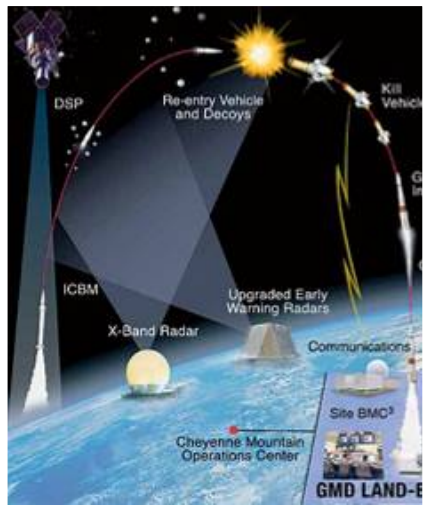
- (4) F/A-18
- (4) F-15E
- (1 system of 4 aircraft) J-UCAS
- (1) B-1B
- (1) F-16
- (1) AWACS 40/45
- (2) BIC Viewing Centers
- (1) Mobile Connexion Van (MCV)

Live-Virtual-Constructive enables Pilots to fly real hardware in live events without live fly costs

Technology Evaluation through Experimentation

- **Experimentation, using M&S, enables exploring the impact of new technology at every level of insertion…before building or buying**
  - **For example, improved sensor and data link capability in A&M aircraft supporting BP counter drug operations (existing military or entirely new)**
  - **Or new counter cruise missile radar/sensor capabilities**
  - **Or better forest firefighting equipment**
  - **Or new WMD detection capabilities**
  - **Or direct hospital to first responder medical support technologies**
  - **Or …**

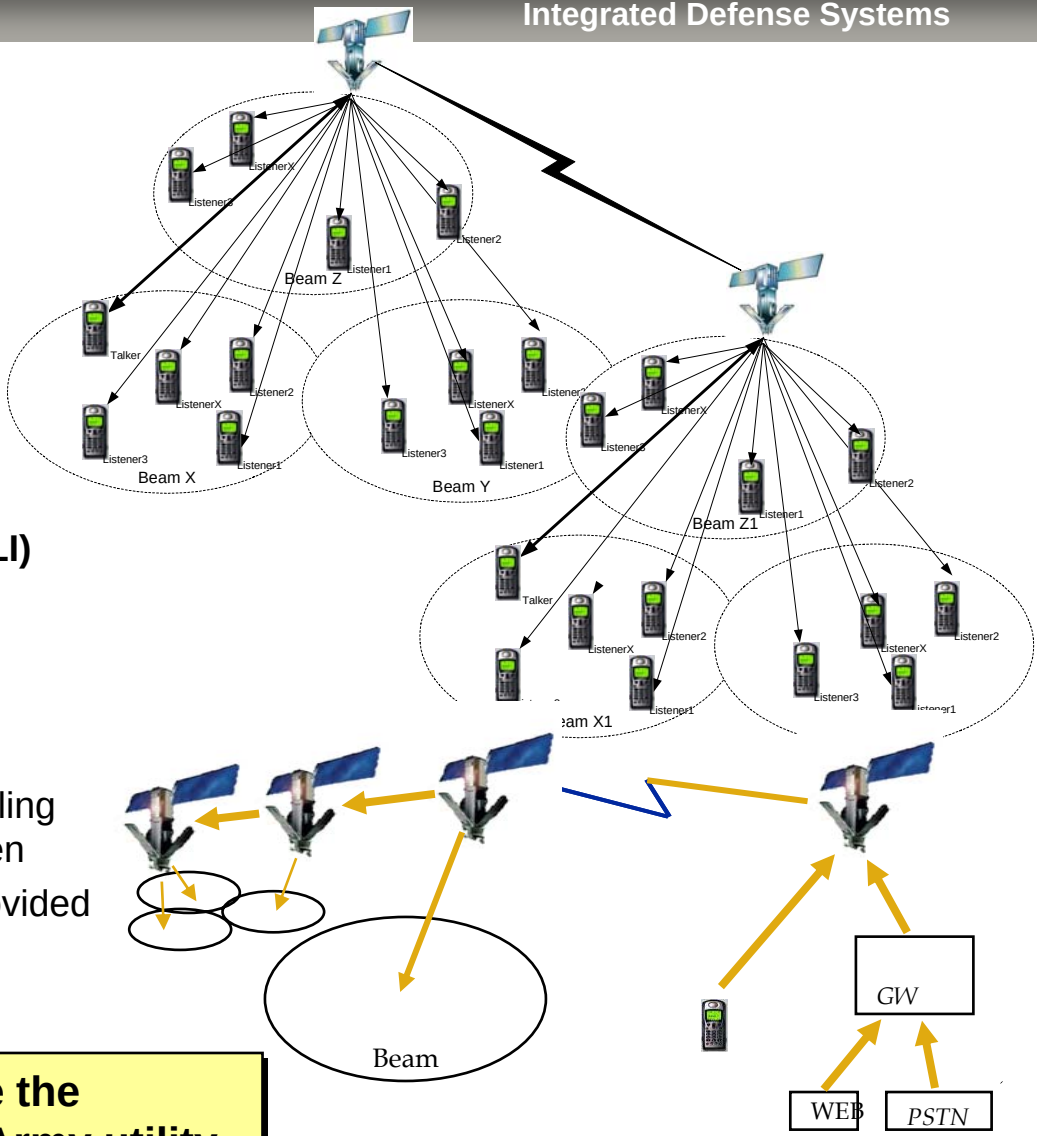




Boeing's & Iridium's "Group Call" On-Orbit Upgrade

Enables Iridium Cellular system to function a "UHF Satcom Radio"

- **Service(s)**
  - **Support DOD customers**
    - **Encrypted service, does not require call intercept**
  - **Three types of Services**
    - **Push to talk (PTT)**
    - **Broadcast**
    - **Position Location Information (PLI)**
  - **GC shall not impact the call performance of non-GC users**
- **Security**
  - All group calls shall be encrypted
  - System shall have the capability of disabling specific users if equipment is lost or stolen
  - Encryption key management shall be provided
  - All group members shall have the latest encryption update prior to joining a GC

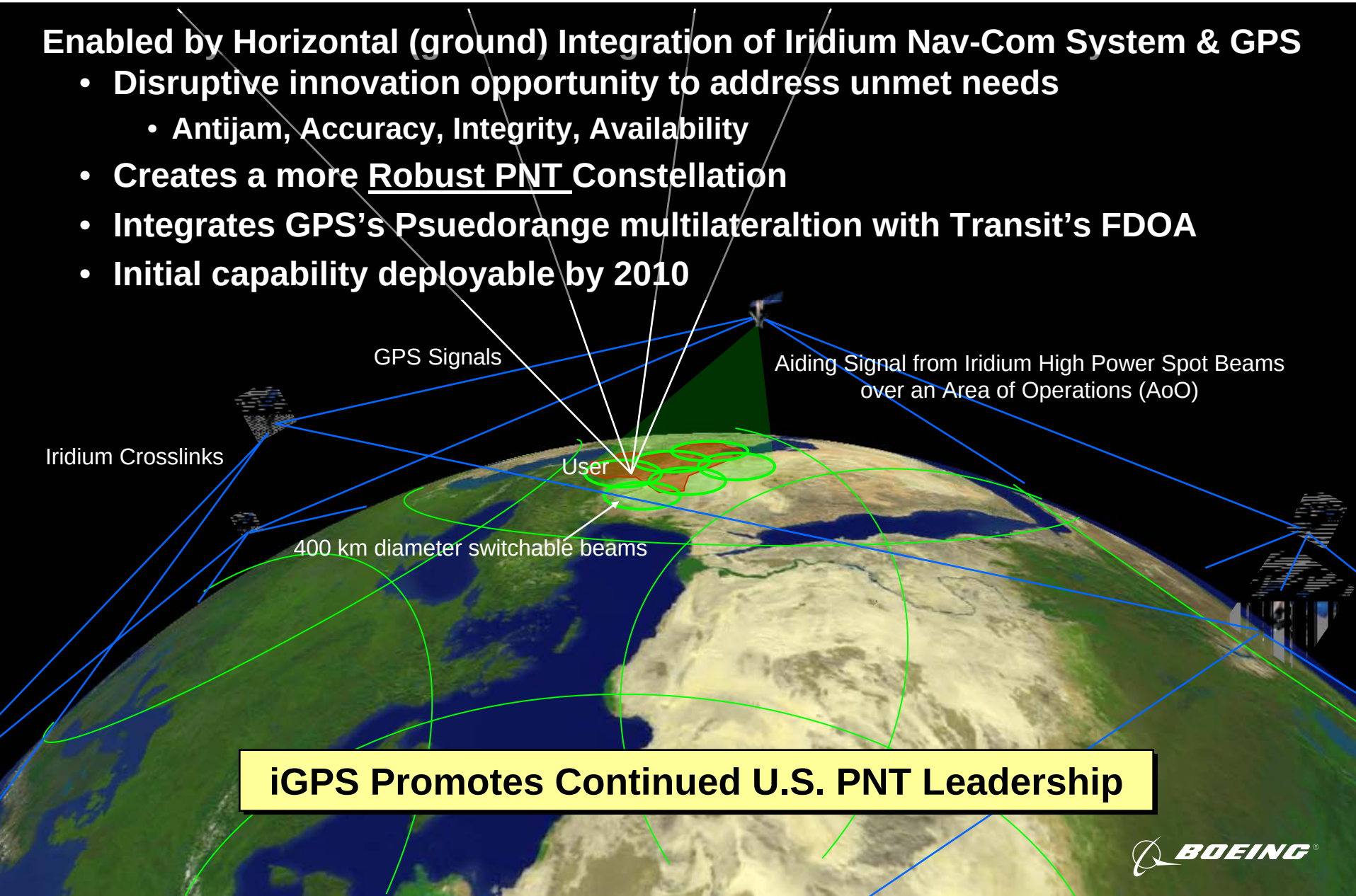


Boeing has already been able to upgrade the constellation to offer new services with Army utility

High Integrity GPS (iGPS Enhancement via Iridium)

Enabled by Horizontal (ground) Integration of Iridium Nav-Com System & GPS

- **Disruptive innovation opportunity to address unmet needs**
  - **Antijam, Accuracy, Integrity, Availability**
- **Creates a more Robust PNT Constellation**
- **Integrates GPS's Psuedorange multilateraltion with Transit's FDOA**
- **Initial capability deployable by 2010**



iGPS Promotes Continued U.S. PNT Leadership

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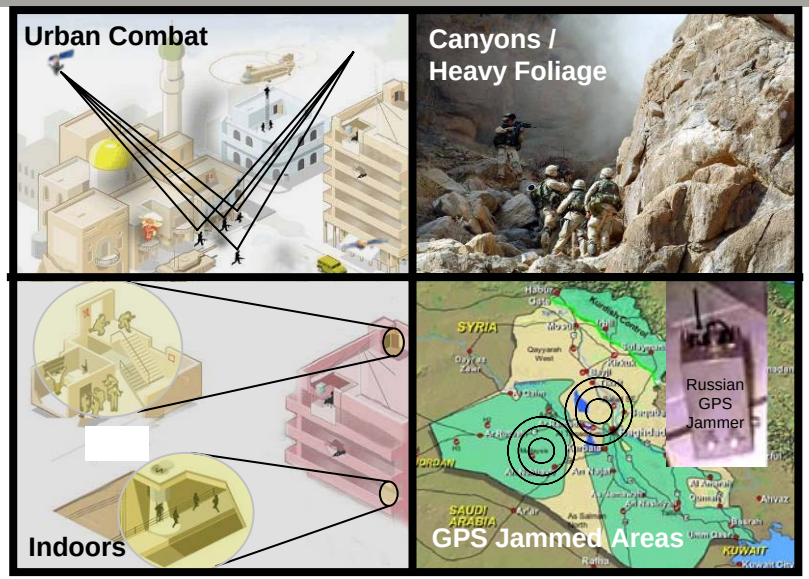
Application: Early SOF iGPS Capability to SOCOM

US Opportunity:

Decisive Navigation Superiority that is Secure and Dependable



- More Robust GPS
  - **Accuracy, integrity, and availability**
- Keep GPS During Electronic Countermeasures
  - **iGPS AJ Prevents ECCM from interfering with DAGR**
- Improve GPS Availability in Restrictive Environments
  - **Forests, Mountainous, Urban**
  - **iGPS Redundant Dynamic Ranging Counteracts Sky Blockage in spite of High Mask Angles**
- Support Global JBFSA
  - **iGPS offers 2-way satellite data link and JBFSA GUI embedded in DAGR**
  - **Network of DAGRs can triangulate enemy jammer locations**
- Rapid (<2 min) Time to First Fix under Severe Jamming (>70 dB J/S)
  - **Improves battery life for extended missions**

A160 Background

- **Autonomous Vertical-UAS utilizing Optimum Speed Rotor technology coupled with other design features to achieve long endurance and long range with significant payload capability**

- **Wide mission range**
  - **C4ISR**
  - **Organic armed ISR**
  - **Utility missions**

- **DARPA-Army program, began in 1998 – presently in Phase I (started Aug 2003)**

Technical Approach

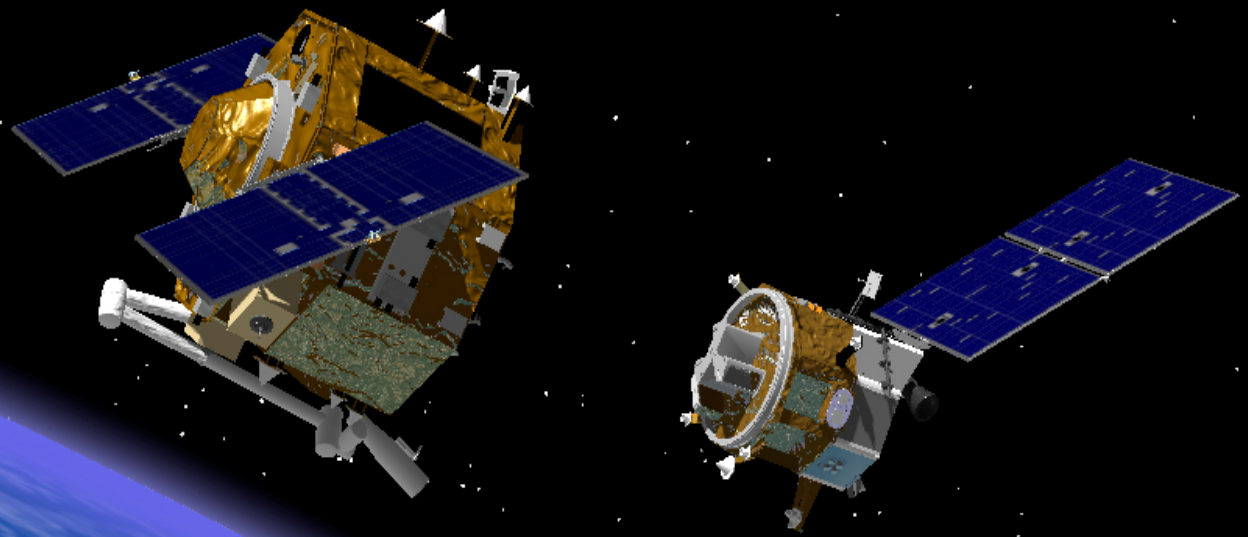
- **Advanced Rotor**
  - **Optimum (Variable) Speed Rotor (OSR), 50-100% RPM**
  - **Low Disk Loading**
  - **High Lift/Drag Blade Airfoils**
  - **Hinge-less Rigid In-Plane Rotor for Precision Control**
- **Fuselage**
  - **Aerodynamically clean retractable main gear**
- **Autonomous Vehicle Flight Control**
  - **Flight Waypoint Control**
  - **Auto take-off and land**
- **Structure**
  - **Lightweight high stiffness blades**
  - **Lightweight fuselage**
- **High Fuel Fraction**

A160 Phase I Performance Goals

- 20 hrs (sea level) endurance with 300 lb payload
- HOGE of 15,000 ft altitude; flight at 30,000 ft altitude
- >2,200 nm range
- Airspeed to 140 knots

- Re-supply delivery of 1000 lb payload to a radius of 500 km
- System reliability to enable 1,000 flight hours between air vehicle losses

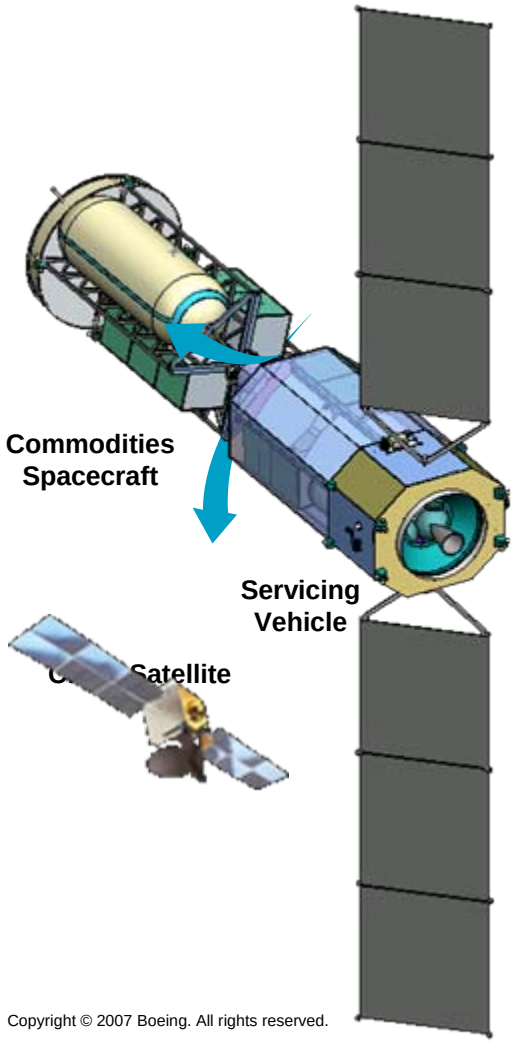
DARPA & Boeing's Orbital Express:
On-orbit servicing enhances space missions



Autonomous Rendezvous & Soft Docking allows:

- **Inspect & service satellites / spacecraft**
- **Deliver commodity consumables / cargo**
- **Assemble large space structures**

Future Systems Enabled by Orbital Express



Demonstrated key technologies to build a future operational system.
The concept of operations provides:

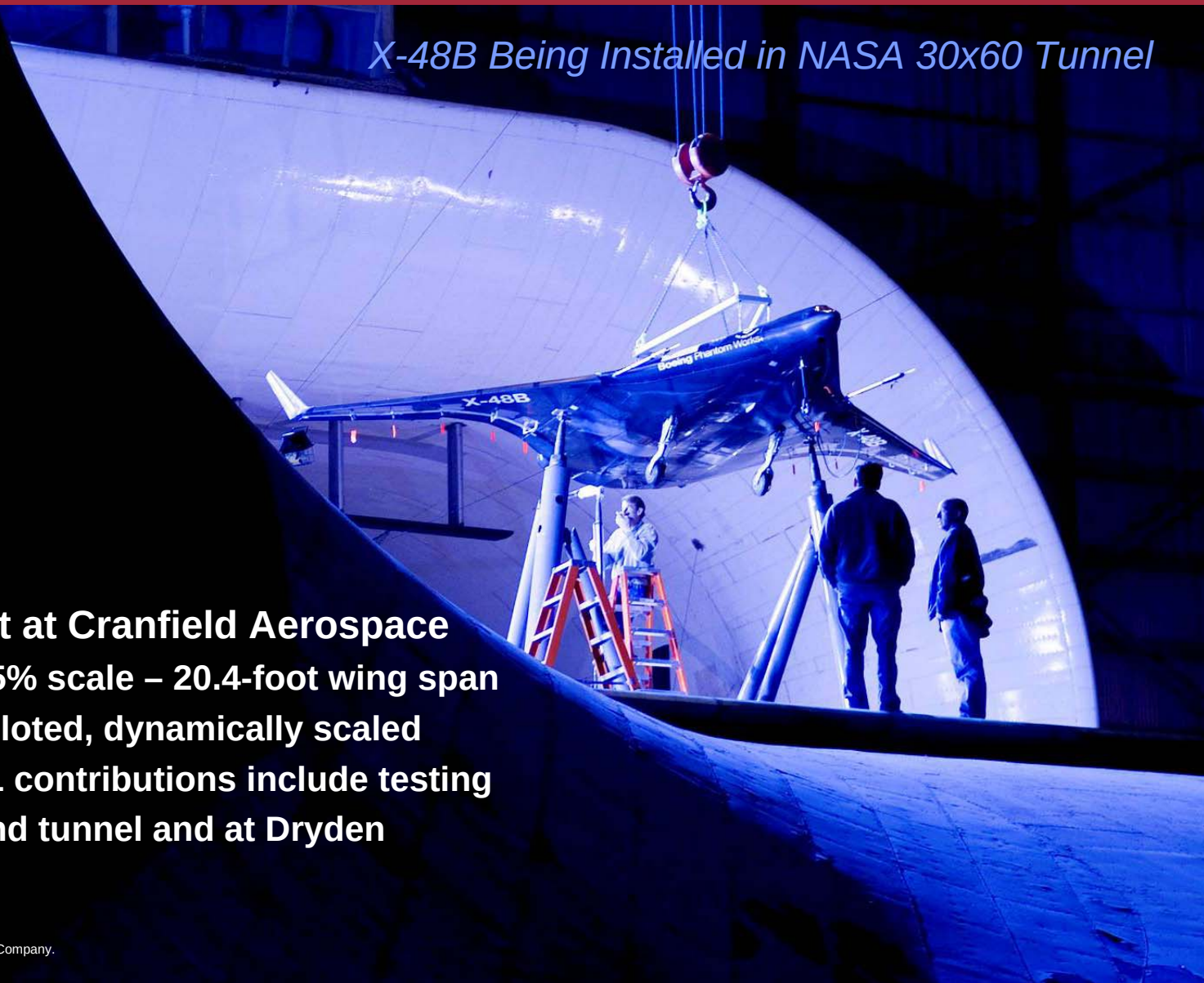
- **A servicing vehicle to rendezvous with client vehicle.**
- **Required services.**
- **Rendezvous with a commodities depot to replenish supplies before servicing the next client vehicle.**

Capabilities enabled by servicing include:

- Refueling
  - Maneuverability
  - Resolution
  - Time over target
  - Repeated access
  - Increased life
  - Randomization
  - Avoidance
  - De orbit
  - Repositioning
  - Contingency refueling
  - Early operational capability
  - Coverage patterns
  - Reduce launch mass
- Replace or upgrade component
  - P3I – new technology infusion
  - Contingency replacement or repair
- On-orbit assembly, test, and checkout
  - Large space optics
  - NASA exploration concepts
- Asset Inspection

Blended Wing Body

X-48B Being Installed in NASA 30x60 Tunnel



Two vehicles built at Cranfield Aerospace

- **Dynamic 8.5% scale – 20.4-foot wing span**
- **Remotely piloted, dynamically scaled**
- **NASA/AFRL contributions include testing in 30x60 wind tunnel and at Dryden**

BWB Low Speed Vehicle (X-48B)

Investigate

- Stall characteristics & departure boundaries
- Asymmetric thrust controllability
- Control surface hinge moments
- Dynamic ground effects

Vehicle Characteristics

- Max Equiv Airspeed: 118 kts
- Max Altitude: 10,000 ft MSL
- Vertical Load Factor Limits: +4.5 to -3.0 g's
- Flight Duration: 30 to 50 min
- Emergency Recovery System (Drogue, Parachute, and Air Bags)

X-48B As Initial Flight Mechanics Risk Reduction

- First flight July 20, 2007; 11 flights completed
- Addressing risk reduction
  - Low speed flight environment
  - Flight mechanics (flight control laws, stability and control characteristics)
  - Secondary Power (control surface / actuator power)

Summary: Transitioning Technology

- Fulfilling Customer Needs via Technology Innovation
- Balance of Technology Push and Systems Pull
- M&S, Experimentation and Demonstrations Critical

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Forever New Frontiers