Future Space Research/Collaboration Opportunities at AFRL

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Outline

• What is AFRL?
• Natural Science Indicators and Implications (but don’t panic)
• Space S&E Outreach at AFRL
  – Space Scholars Program
  – University Nanosat Program
  – NRC & ASEE Research Fellows
  – Other Programs
Outline

• What is AFRL?
• Natural Science Indicators and Implications (but don’t panic)
• Space S&E Outreach at AFRL
  – Space Scholars Program
  – University Nanosat Program
  – NRC & ASEE Research Fellows
  – Other Programs
The mission of the United States Air Force is to fly, fight and win...

Air, Space, Cyberspace

Guides USAF S&T goals

Cyber

Links S&T to Warfighter
Leading the discovery, development, and integration of affordable warfighting technologies for our air, space and cyberspace force.

It’s not just about the science…
…it’s about leadership in S&T
What are our major future Challenges in each domain?
Challenges – Overarching: Political / Economic / Cultural Realities

• Inevitable rise of Peer Nations
  – Near-Peer…then Peer…then perhaps surpassing U.S. in some or many areas

• Need for multi-dimensional approach to rise of violent extremism
  – Requires use of all elements of power (Pol-Mil-Econ-Soc-Cult)

• Policy changes of new U.S. administration
  – Direction
  – Budget

• Potential loss of U.S. competitiveness
  – If we become risk-averse vs risk-taking (forward leaning)
Challenges by Domain

- **Air:** Persistent air dominance is at risk
  - Increasingly effective air defenses
  - Proliferation of 5th gen fighters, cheap cruise missiles, and UASs
  - Light-speed war possibilities are terrifying
- **Space:** Now a contested domain – dominance at risk
  - Increasingly important
  - Increasingly vulnerable
- **Cyber:** Cyber warfare has begun
  - We don’t control the battlespace
  - We rely on it more and more
  - We can’t find the enemy
What can S&T do to help the Air Force meet these Challenges?
Opportunities – Air:
Across the Technology Spectrum

• **Endurance** – Efficient aerodynamics, efficient propulsion, lightweight structures
• **Alternative Fuels** – Fischer-Tropsch, biomass, carbon sequestration
• **Sensors** – 360 degree coverage, structural load-bearing antennas
• **Speed** – Hypersonics, thermal, flight controls, maneuverability, payloads
• **Thermal Management** – Produce less heat, tolerate more heat, dissipate more efficiently, convert more effectively
• **Modeling & Simulation** – Virtual prototyping, live-virtual-constructive environments
• **Manufacturing Technology** – Lean, diagnostics, just-in-time production
• **UASs** – Swarming, semi-autonomous then autonomous, learning, healing
• **Micro Air Vehicles** – Sensor miniaturization, flight agility, autonomy
• **Integrated Systems Health Management** – Self-reporting systems, autonomous reconfiguration to maintain mission capability
• **Responsive** to needs of sister services, needs of the Nation
Opportunities – Air: “We Can Control the Vertical”

- **C²ISR (High-to-Medium Altitudes)**
  - Endurance
    - Aerodynamics
    - Propulsion
  - Layered Sensing
    - Sensors
    - Processing & Integration

- **ATTACK (Medium Altitudes)**
  - Swarming Brains (UAVs)
    - Programming & Processing

- **URBAN & SOLIC (Low Altitudes)**
  - Maneuverability
    - Morphing structures, bio-mimetics
  - Miniaturization
    - Micro- & Nano-
  - Autonomy
    - Sensors
    - Game Theory & Processing
Opportunities – Space: SSA & ORS

• Space Situational Awareness
  – High resolution imaging
  – Electro-optical phenomenology
  – Advanced astrodynamics
  – Modeling and decision aids

• Operationally Responsive Space
  – Plug ‘n’ Play Satellites
  – Small vs Large Satellites
  – Quick Launch
  – Fast On-Orbit Checkout
  – Tactical Space
Opportunities – Cyber:
We need to completely re-think this!

- Anti-access strategies are unlikely to be successful
- Offense is Sexy and “War-Fighter Cool”…
- …but Defense is far, far more important!
- I would give up ALL my Cyber Offense capability to have a Robust Cyber Defense!
- Denial of service—in this area, at least, we are ahead of our adversaries
- "One Air Force – One Network" is a really poor vision for the future
Opportunities – Cyber: Robust, Resistant, Resilient

- Must be able to take a **series** of punches, jabs, feints...and survive!
- “Fight **through** the Attack!”
  - Endure...mitigate...recover... reconstitute...get up...move forward!
- Move beyond “One Air Force – One Network” to “Defending the Nation”
- Evolve to a polymorphic system of systems that naturally favors:
  - Stability
  - Security
  - Cyber-Sensing
  - Partitionable
  - Rapid Reconstitution
  - Focus on Protecting & Delivering Data
Ten Technical Directorates

- Directed Energy
- AFOSR
- Space Vehicles
- Human Effectiveness
- Munitions
- Materials & Manufacturing
- Sensors
- Propulsion
- Information
- Air Vehicles
## AFRL Workforce

<table>
<thead>
<tr>
<th>Employees</th>
<th>Civilian</th>
<th>Military</th>
<th>Contractor</th>
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<tr>
<td>Total</td>
<td>~10800</td>
<td>~4750</td>
<td>~4600</td>
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<tr>
<td>S&amp;Es</td>
<td>~ 6750</td>
<td>~2800</td>
<td>~3100</td>
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</table>

### Civilian S&E Education

- 43% B.S
- 29% M.S
- 28% PhD

### Education Level by Grade

<table>
<thead>
<tr>
<th>Grade</th>
<th>PhD</th>
<th>M.S</th>
<th>B.S</th>
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Funding Leverage

AFRL
$2.1 Billion

+ 

External Funds
$2.1 Billion

Thousands of Knowledge Providers

FY08 Appropriated Funding

IN-HOUSE
INDUSTRY
SMALL BUSINESS
ACADEMIA
NATIONAL LABS
We support both the current fight and the future Air Force

**Lead Discovery**

Generate
Understanding of Scientific and Technical Opportunities

Long-Term Focus
Lead / Discover
Core Process 1

**Requirements Pull**

Deliver
Needed Technology Options
Mid-Term Focus
Develop / Deliver
Core Process 2

**Rapid Response**

Innovate
Solutions to Near-Term Needs
Near-Term Focus
Solve / Deliver
Core Process 3

**Deliver Knowledge**

Train
Aerospace Medical Specialties
Near-Term Focus
Develop / Deliver
Core Process 4

*ANYTHING, ANYTIME, ANYWHERE*
Anticipatory Command, Control & Intelligence (C2I)

Unprecedented Proactive Intelligence, Surveillance and Reconnaissance (ISR)

Dominant Difficult Surface Target Engagement/Defeat

Persistent & Responsive Precision Engagement

Assured Operations in High Threat Environments

Dominant Offensive Cyber Engagement

On-demand Force Projection, Anywhere

Affordable Mission Generation & Sustainment

Questions the Air Force doesn’t even know to ask
We support both the current fight and the future Air Force.

**Generate**
Understanding of Scientific and Technical Opportunities

- Long-Term Focus
  - Lead / Discover
  - Core Process 1

**Deliver**
Needed Technology Options

- Mid-Term Focus
  - Develop / Deliver
  - Core Process 2

**Innovate**
Solutions to Near-Term Needs

- Near-Term Focus
  - Solve / Deliver
  - Core Process 3

**Train**
Aerospace Medical Specialties

- Near-Term Focus
  - Develop / Deliver
  - Core Process 4
Core Process 2
Develop & Deliver Needed Technology Options

- Mid-Term Commitment
- Develop / deliver what the customer needs

Advanced Technology Demonstrations (ATDs)
- Larger scale 6.3 efforts
- Direct user involvement
- Established baseline
- Clear transition target
- Commissioned by ATC

Developing technology options that meet the needs of capability developers
We support both the current fight and the future Air Force

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### Core Process 3
Innovate Solutions to Near Term Needs

- Meeting Warfighters Near-term Needs
- Rapidly deliver technical innovation, driven by user emergencies
- Special interest, high priority operations support
- Capitalize on breadth and depth of AFRL’s expertise

#### Air
- Micro-Air Vehicle
- Persistent ISR
- Horizontal Stabilizer
- Main Landing Gear Door Yoke Assembly
- Robots for IED's
- Helo Brownout

#### Space
- XSS-11
- JSpOC 3.0
- JSpOC Situational Awareness and Reporting System

#### Cyber
- UAV Ops Center
- Psychological Operation Decision Aids

**Accelerating Technology Development and Demonstration for Warfighter Needs**
• Apply operational aircraft concepts to space systems
  • Tailored mission capabilities
  • Rapid Build-Up/Turn times
  • Air Tasking Order responsiveness
  • Satellite buses with plug-and-play payloads
  • Sustained high operations tempo
JSpOC Situation Awareness and Response System (JSARS)

- Problem:
  - DoD Space assets are susceptible to numerous threats
  - Must detect and distinguish between environmental, man-made, and unintentional acts

- Near Term Solution: Exploitation of available data to provide space situational awareness (SSA)
  - Space weather, ground site RF environment, satellite telemetry, proximity and conjunctions

- AFRL developed prototype solution in 9 months and delivered to Joint Space Operations Center (JSpOC) in Oct 2007
The Art of Science & Technology

- S&T Nirvana: Healthy Balance / Tension in these:
  - Requirements: Customer Pulls / Lab “Eureka!” Pushes
  - Research: Internal Lab / External Academic & Industry
  - Funding: Internal AF / External Customers
  - Focus: Current Urgent Needs / Future Important Vision
  - Risk: Assuring Tech Transition / High-Payoff Concepts

- Achieving Dynamic Stability…Just Barely!
- Balancing these is our most important and difficult responsibility. We think we’re getting it about right.

The Air Force Mission is an extremely challenging, increasingly complex and inherently technical activity that requires a highly educated technical workforce
We Need Competent S&Es

INNOVATION
Is Best Left to Those With a Clue
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Trends in Baccalaureates

• Baccalaureates Awarded to US Citizens
  – ~60,000 in engineering annually (steady)
  – ~160,000 in all natural sciences (steady)

• Baccalaureates Awarded in Asia
  – ~380,000 in engineering annually (+20K/year)
  – ~520,000 in all natural sciences (+20K/year)

• For Reference: In 1985 US awarded about same number of Engineering BS degrees as Asia, annually

Data for year 2000, collected from NSF and 2000 Census
Trends in PhD’s

• PhD’s in all Natural Sciences (2000 data)
  – ~9000 annually in U.S.A
    • Over 50% of these awarded to foreign nationals
    • US-educated PhD’s are populating newly proliferated educational institutions in Asia
  – ~16000 annually in Asia
    – Up from 9000 in 1996 (almost doubled in 4 years)

• Worldmapper reports US rank as #12 in the number of scientific papers per capita worldwide
  – But US not listed among the top 30 nations for increases of papers per capita
• Total 2003 S&T/R&D Investment in US: $252B
• Total 2003 Tort Litigation Costs: $248B
• US has a shrinking percentage of world’s technical workforce, but has roughly 80% of the world’s lawyers
• 1972 poll indicated most American’s didn’t know how to find a lawyer
• 2007 poll indicated most American’s don’t know an engineer
• Tort cost as function of GDP
  – 1950: 0.62%
  – 2005: 2.1%
A Rare Breed
(A Profound Responsibility)

• ~ 190M people in US over age of 25
• ~44M US adults have a college degree (23%)
• ~9M have a graduate degree (5%)
• ~7M have a natural science degree (3.6%)
• ~3.5M engineers (<2%)
• ~700K with graduate degrees in Engineering (0.5%)
The “Knack”
An Optimists View

• Engineers: Modern day wizards
• How Oft do we hear, “People are our most important resource”?  
  – S&E’s are more than an “Important Resource”, they are a national treasure who precipitate future reality from imagination  
  – S&E’s generate the commodities, products and services that spawn industries and fuel economic engines and the rest of the world KNOWS THIS!
An Optimists View

• More technology, not less
  – Question is not “if”, but “who”

• Epictetus: Only the Educated are Free

• Fredrick Douglas: An educated man is unfit as a slave

• John Adams: Liberty cannot be preserved without and educated public

• Implication: An educated public cannot be kept enslaved
An Optimist View

• US possesses great inner-strength
  – Still the freest nation in the world
  – Rich natural resources allow national independence
  – Our Constitutional liberties, if preserved, guarantee the essential ingredients, incentives, and rugged individualism that have propelled our nation to preeminence

• A “rising” Asia: an educated Asia: a liberated Asia is not the challenge

• The challenge is to hold firm to the principles of enlightenment and liberty we’ve inherited from our forebears – and to pass it on to the rising generation
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Education Outreach & Recruiting: RV’s Pipeline

University Interactions
- Space Scholars
- Junior Scholars
- University NanoSat Program
- Ed. Partnership Agreements
- NRC Res Assoc/ASEE Summer Faculty
- NDSEG Fellowships

K-12: AFRL La Luz Academy
Mars Flight
PETES Flight
SPACE Flight
Teacher Institute

Professional Development
Sys Eng Grad Certificates
Adjunct Professors
50-60 Scholars Mentors/yr
Scholars Programs
(Space Scholars/DE Scholars)

A Joint AFOSR-AFRL/RV Outreach Program

- The best and brightest science and engineering students from the United States
- performing cutting-edge research at AFRL laboratory facilities
- in a summer laboratory internship geared to current and future Air Force technology needs,
- mentored by world-renowned AFRL researchers.

Train, Nurture, and Mentor the Nation’s Future Scientists & Engineers and while performing research of significance and value to the Air Force
Objectives

Enhance AFRL basic research
Provide research opportunities to students
Recruitment & Mentoring opportunities
Enhance communications with Academia
Space Scholars
2008 Participating Universities

Slide courtesy of Jeaninne Ortiz (AFRL/RVIL)
2008 Keynote Speakers

Gen Simon “Pete” Worden (Ret., USAF), NASA Ames Director

Gen Paul Nielsen (Ret., USAF), Director & CEO of the Software Engineering Institute at Carnegie Mellon University & AIAA President

Dr. James Voss, Retired Shuttle Astronaut & Vice-President of SpaceDev
Recent Research Projects (I)

Solving Relative Orbit Geometry using Angles-Only Navigation

Localized Satellite Drag Modeling

Development of a Symbiotic Thermal-Structural Satellite Panel
Past Speakers

Prof. Daniel Hastings, MIT, Former Chief Scientist of USAF, Current Chair of USAF Scientific Advisory Board (2005)

Dr. Peter Diamandis, Chairman, Ansari X-Prize Foundation (2006)

Prof. Richard Smalley, Rice University, Nobel Laureate Winner in Physics (2003)

MGen John “Tom” Sheridan, Program Executive Officer and System Program Director, Space Radar Program (2006)

Mr. Elon Musk, founder of PayPal, CEO and CTO, Space-X Corp (2005)

Prof. Neal Lane, Rice University, former director of NSF, former Science Advisor to President Bill Clinton (2005)

Prof. Steven Chu, Stanford, Nobel Laureate Winner in Physics (2003)

Dr. Maw-Kuen Wu, Academica Sinica, Former Minister of the National Science Council of Taiwan (2006)

Dr. Tom Bowles, Chief Scientist, Los Alamos National Laboratories, Science Adviser to NM Gov Bill Richardson (2007)
Recent Research Projects (II)

- Using Particle Image Velocimetry to characterize flow in Pulse-Tube Cryocoolers
- Modeling of Photospheric Magnetic Fields
- Development of Space Plug-and-play Avionics Hardware
Recent Research Projects (V)

Development of an Elastically Deployable Boom for a Solar Sail

Advanced Deployable Structure Technology Based on the Concentrated Strain Approach
Program Schedule & Info

- Space Scholars & DE Scholars websites are:
  - http://www.vs.afrl.af.mil/SpaceScholars/
  - http://www.de.afrl.af.mil/Scholars/
- Topics & mentor bios to be published around mid-October; applications will begin then
- Application deadline TBD (likely late December/early January)
- Offers made February/March
A continuing effort to develop highly trained, US university students by teaching hands-on systems engineering through design, AI&T, launch and on-orbit operation of student-built nanosatellites.

http://www.vs.afrl.af.mil/UNP/
UNP Reach

27 universities and ~4000 students since 1999
Skill Set

The two-year Nanosat cycle includes:

- Five detailed reviews
- Two hands-on training workshops using high altitude balloons
- One satellite fabrication course
- Fourteen expert area telecons

Through this process, our graduates learn:

- Systems engineering
- Risk management
- System and subsystem design
- Analysis
- Interdependency and teamwork
- Acquisition management
- Schedule and cost constraints
- System and subsystem integration and test
Project Objectives
• Study ionospheric disturbances
• Measure upper atmosphere cloud formation
• Simulate formation flying capability
• Flight demonstration to two types of AFRL SBIR-developed low-shock release mechanisms
  – Planetary Systems Corp. Standard Lightband
  – Starsys Research Corp. CBOD Clampband Device

Technical Innovation/Approach
• “Virtual” constellation of three identical, independent satellites built by three separate universities (NMSU, ASU and UC-Boulder)

Impacts/Benefits
• Workforce development—experienced Three Corner Sat student alumni continued into industry/government positions

Dec 2004 – Nanosat-2 Launched on the Delta 4 Heavy Demo Mission
  – High-visibility responsive launch integration, on-time & on-budget
  – Sole STP launch for CY2004
  – First auxiliary payload to launch on EELV
Nanosat-3 (FASTRAC)
Flight Overview/Status

FASTRAC = Formation Autonomous Satellite with Thrust, Rel-nav & Crosslink

Project Objectives
• Demonstration of student-built differential GPS rel-nav, and autonomous microthruster experiments
• Flight demonstration of AFRL-developed linerless composite propellant tank

Technical Innovation/Approach
• Relative navigation between spacecraft to meter resolution
• Autonomous orbit maintenance using micropropulsion
  – Verified by GPS telemetry, potentially by ground-based tracking

Impacts/Benefits
• Workforce development—experienced FASTRAC student alumni have been hired into industry/government positions
• First flight of meter-resolution GPS rel-nav

Current Status
• At AFRL/RV KAFB for environmental T&E
• Scheduled Launch Date: May 2010 on Minotaur from Kodiak (STP 26)
Nanosat-4,5

- **Nanosat-4 Flight Winner - Cornell University Satellite (CUSat)**
  - Built by Cornell Univ.
  - Demonstrate on-orbit Carrier-phase Differential GPS can support inspection operations
  - At KAFB undergoing environmental T&E
  - Possible launch May 2010

- **Nanosat-5 Flight Winner - Drag and Atmospheric Neutral Density Explorer (DANDE)**
  - Built by Univ. of Colorado at Boulder
  - Measure density, composition and winds at 350km to 200 km altitudes
Current UNP Participants

- **Nanosat-6 Flight Winner Selected in January 2011**
  - Univ. of Hawaii – Radar calibration
  - Santa Clara Univ. – Intelligent responsive imaging
  - Univ. of Central Florida – Gossamer technology
  - MIT – Orbital transfer vehicle
  - Georgia Tech – Rapid reconnaissance and response
  - Michigan Tech – Calibration for attitude and shape recognition models
  - Univ. of Minnesota – GPS bistatic radar
  - Missouri Univ. of Science & Technology – Close formation flight
  - Montana State Univ. – Space weather
  - Cornell Univ. – Small CMG prototypes and steering laws
  - Washington Univ. in St. Louis – Situational awareness using a team of four deployable spacecraft
## UNP Events

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<th>Nanosat-3 University of Texas at Austin</th>
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<td>Fall 2008</td>
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<td>May 2010</td>
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### Nanosat-4 Cornell University

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<td>March 2006</td>
<td>Nanosat-4 Flight Competition Review -- CUSat named winner</td>
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<tr>
<td>March 2008</td>
<td>CUSat delivered to AFRL</td>
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### Nanosat-5 University of Colorado at Boulder

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<tbody>
<tr>
<td>Jan 2009</td>
<td>Nanosat-5 Flight Competition Review – DANDE named winner</td>
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### Nanosat-6

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<tr>
<td>Spring 2009</td>
<td>System Concept Review</td>
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<tr>
<td>Spring 2009</td>
<td>System Requirements Review</td>
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<tr>
<td>Summer 2009</td>
<td>Student Hands-On Training (SHOT) 1 in Boulder, CO</td>
</tr>
<tr>
<td>Aug 2009</td>
<td>Preliminary Design Review at SmallSat Conference in Logan, UT</td>
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<tr>
<td>Fall 2009</td>
<td>Satellite Fabrication class at AFRL</td>
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<tr>
<td>Spring 2010</td>
<td>Critical Design Review at each university</td>
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<tr>
<td>Summer 2010</td>
<td>SHOT 2 in Boulder, CO</td>
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<tr>
<td>Aug 2010</td>
<td>Proto-Qualification Review at SmallSat Conference in Logan, UT</td>
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<tr>
<td>Jan 2011</td>
<td>Flight Competition Review</td>
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UNP Financial Partnerships

- Air Force Research Laboratory
  - Air Force Office of Scientific Research (AFOSR)
  - Space Vehicles Directorate (AFRL/RV)

- Contribution
  - $1.4M each organization per 2-year Cycle

- Funded Participants per 2-year Cycle
  - 11 Universities at $110K each
  - 1 Finalist at $110K additional funds
  - 2 Fulltime Equivalent Program Managers
UNP I&T and Launch

• Test Plans
• Test Plan Development
• Functional Tests
• Environmental Tests
  • Vibe Testing
  • T-Vac Testing
  • EMI/EMC
  • CG/MOI
  • Solar Simulator
  • End to End Tests
• Launch
University Nanosat Program

- Energizes a Professional Pipeline of Space Workforce
- Preserves US Technological Dominance in Satellite Technology
- Builds Scientific Collaborations
  - Government
  - Academia
  - Industry
- Develops Innovative Solutions to Space Challenges
University Nanosat Program
http://www.vs.afrl.af.mil/UNP/index.html

For more information contact Abbie Stovall
505-235-9230 or abbie.stewart@us.af.mil
Other Visiting Scholar Programs & Educational Programs

• NRC Research Fellows (Faculty & PostDoc)
  – http://www7.nationalacademies.org/rap/

• ASEE Summer Faculty Fellowships (Faculty, Summer)
  – http://asee.org/sffp/ (Deadline: 1 November)

• NDSEG Fellowships (undergrad/1st-year MS)
  – http://asee.org/resources/fellowships/ndseg/index.cfm

• Palace Acquire Program (undergrads MS, commitment)

• SMART Program (2 years, all levels, follow-on commitment)
  – http://asee.org/resources/fellowships/smart/index.cfm (Deadline: February)

• Educational Partnership Agreements (continuing)
  – http://www.vs.afrl.af.mil/TechOutreach/TT/
Summary

• RV has strong outreach programs with Academia
  – Space Scholars
  – University Nanosat Program
  – ASEE Summer Faculty/NRC Research Fellows
  – Other Programs

• Programs are actively managed to strategic objectives
  – BRAC
  – Recruiting
  – New research Areas

• These programs are active partnerships with AFOSR
  – Kent Miller, Leslie Peasant, Kathleen Kaplan

Questions?