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Unmanned Aerial Systems (UAS) for Precision Agriculture and Pest Control Uses

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Auburn, AL 36830

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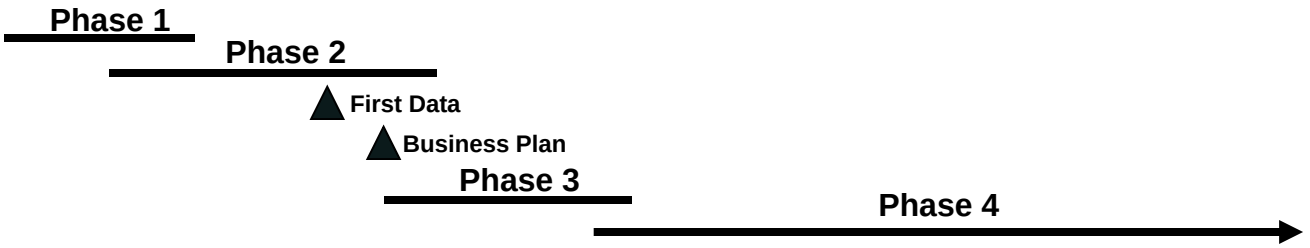
Background

- **Advanced Technology Associates (Littleton, CO) and Corporate Air (Billings, MT)**
  - Have established a working group aimed at developing a major center for UAS applications in Montana
    - Corporate Air does business world-wide, so is well known in MT
  - Plan to develop an affordable UAS for commercial uses
    - Remote sensing for agriculture, forestry and other applications
    - Priority depends on user response and funding
- **Auburn has been involved**
  - Agricultural inputs provided
  - Some forestry applications discussed (Pine bark beetles)
  - Open to having Auburn (and Alabama) a test site
    - When vehicle and infrastructure permit
    - But specifics of needs need clarification
    - Crops, pests, etc.

UAS Program Phases

- **Phase 1 (Public Funding)**
  - Proof of Principle
  - Fixed Wing Aircraft
  - Developmental Avionics
- **Phase 2 (Public Funding)**
  - UAS Preliminary Design and Flight Test
  - Initial Integrated Flight Data
  - Business Plan Completed
- **Phase 3 (Private Funding)**
  - Flight Certification
  - Multi-Flight Certification
- **Phase 4 (Private Funding)**
  - Build Required Fleet
  - Operations



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Present Industry Working Group

Organization/Location	Contact Name	Roles/Responsibilities
Advanced Technology Associates, Inc. (ATA) Colorado/Montana	David Scruggs/Grant Williams	Program Management / Software /Systems/ Business Management
Schafer Corporation/ Alabama	Bruce Peters Ph.D.	Communications
Resonon Inc./ Montana	Rand Swanson	Hyperspectral Sensors
Innovative Integration/ California	Dan McLane	Digital Hardware
Carbon-Free Energy, LLC / Alabama	Henry Brandhorst Ph.D.	Systems Requirements/Coordination
Montana State Univ.	Rick Lawrence Ph.D.	Biosystems
Stratom/Colorado	Mark Gordon	Robotics
Corporate Air/Montana	Mike Overstreet	Operations
Colorado School of Mines/Colorado	Robert King Ph.D.	Vehicle Design/Sensors/Geology

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Non-Military Markets

Border Surveillance	Pipe/Power Line Surveillance
Suspect Tracking	Agricultural Applications
Traffic Monitoring	Communications/Broadcast
Disaster Response/Relief	Movie Production
Damage Assessment	Aerial News Coverage
Atmospheric/Weather Research	Mail/Freight Transport
Critical Infrastructure Monitoring	Flood Mapping
Damage Surveying	Real-estate Mapping
Aerial Photography	Mining
Wildlife Monitoring	Sporting Event Coverage

Source: Association Unmanned Vehicle Systems International 2010

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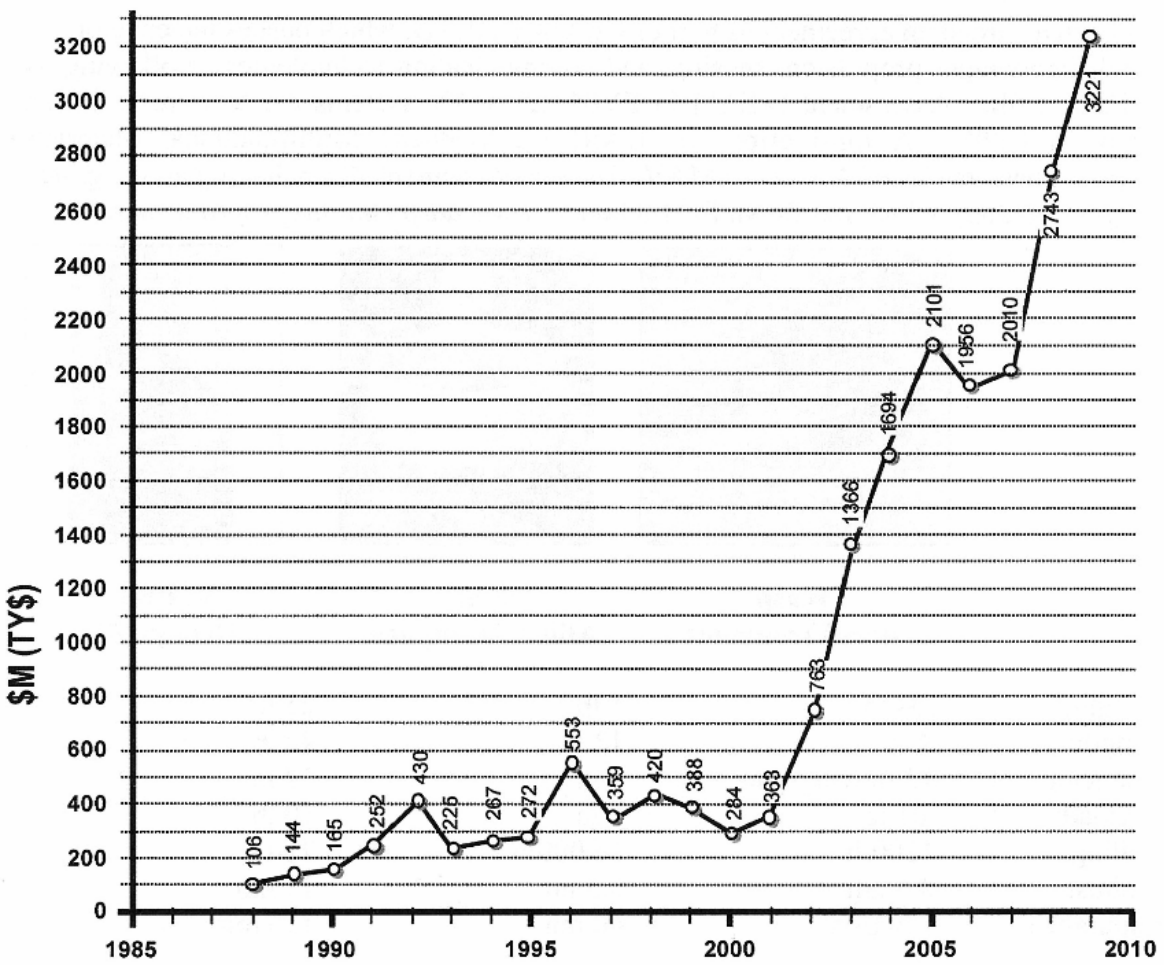
DoD Annual Funding Profile for UAVs



- Exponential Growth
  - 2009 All Market Growth
    - $3.5 B
  - 2010 All Market Growth
    - $7.5 B
  - 2010 to 2015 DoD Market
  - $68 B
- **Commercial Market U.S.**
  - Limited to Research
  - $200 M/Y
  - We're hoping to help increase this funding sector
    - Expect it to be VERY large
    - Regional agricultural and forestry market differences

Source: Association Unmanned Vehicle Systems International 2010

Current Activities

- **Why Montana?**
  - Corporate Air is Headquartered in Billings, Montana
  - Montana Governor — Brian Schweitzer
    - Supports the Program
  - Montana Senators – Max Baucus and Jon Tester
    - Support the Program
  - Montana has Two of the Largest and Unused Military Operations Areas (MOA)
  - Montana wants to become the FAA's Center of Excellence for UAS's
    - Montana wants an Aerospace Industry also
  - Montana has Pine Bark Beetles and agriculture too!
- **What are the issues for UASs and forestry/agriculture**
  - Pine Bark Beetles specifically

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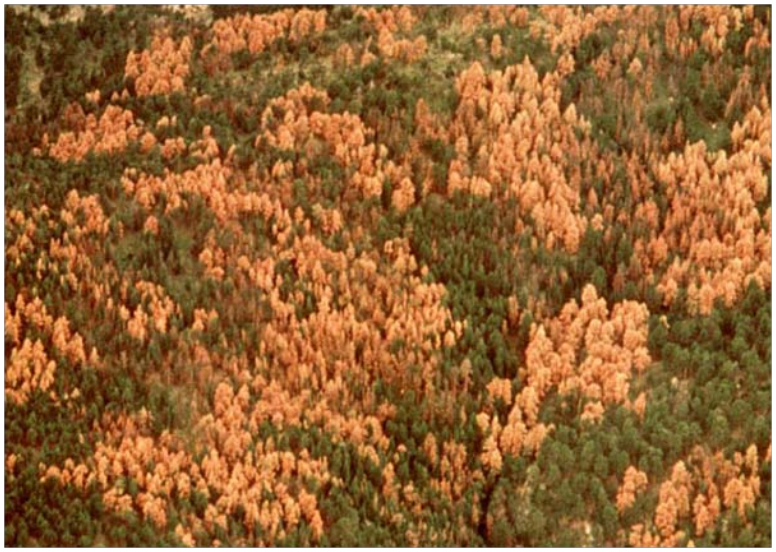
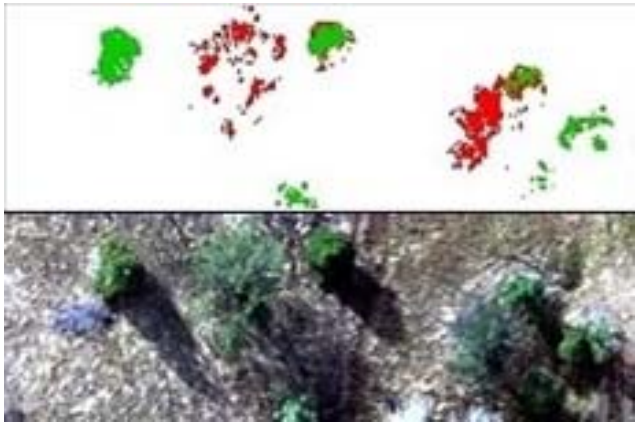
Pine Bark Beetles

- **About 54% of the U.S. tree losses are attributed to scolytids**
  - Distribution of mortality tends to be clumpy
- **Mountain Pine Beetle: 1 yr. life**
  - #1 mortality agent in western pines
  - Flies from dead trees to live ones in July-August – range ~1 mile
    - Up to 70 miles in wind!
  - Develop in the phloem tissue under the bark
  - Carry blue stain fungus
- **Signs of infestation**
  - Usually found on foot
    - Pitch tubes, boring dust, woodpeckers
  - However, due to the distributed nature of the infestation, tracking on foot is problematic



Pine Bark Beetles

- **Fading of the tree crowns**
  - Usually occurs ~9-10 months after attack (April-June)
  - Whole crown changes color rather uniformly
  - When followed on foot it takes a long time to identify all the clumps
  - Use of airplanes has not been cost effective
    - Location mapping inaccurate
    - Cost of pilots and observer(s)
    - Limited flying time/area coverage
- **The UAS may help solve these limitations**
  - Hyperspectral imaging may identify infestations earlier than on foot
    - High position accuracy easy
  - But only limited data available
    - Your inputs needed



Airborne image of pine trees and juniper bushes: Classification map (top) - Real color (bottom) Juniper (green) and Pine (red)

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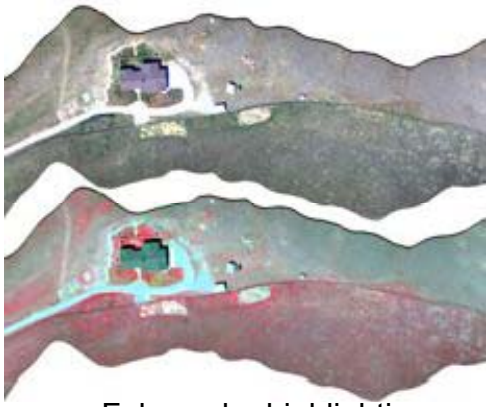
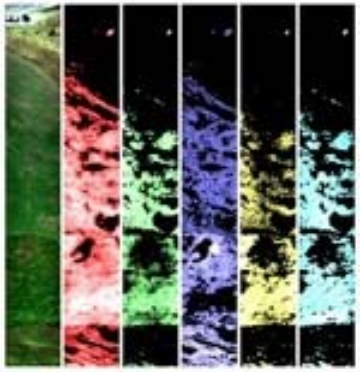
Hyperspectral Imaging

- **Airborne imaging spectrometer system**
  - Imaging spectrometer
  - Data acquisition computer
  - Interface for collecting GPS/IMU data
  - System control software
  - Geo-rectified image data using attitude/position data
- **Data reduction and analysis**
  - This is the tricky part
  - Requires signature identification through ground truth
  - Key spectral bands identify infestation, weeds, fuel loading in forests, etc…
  - Image processing software available

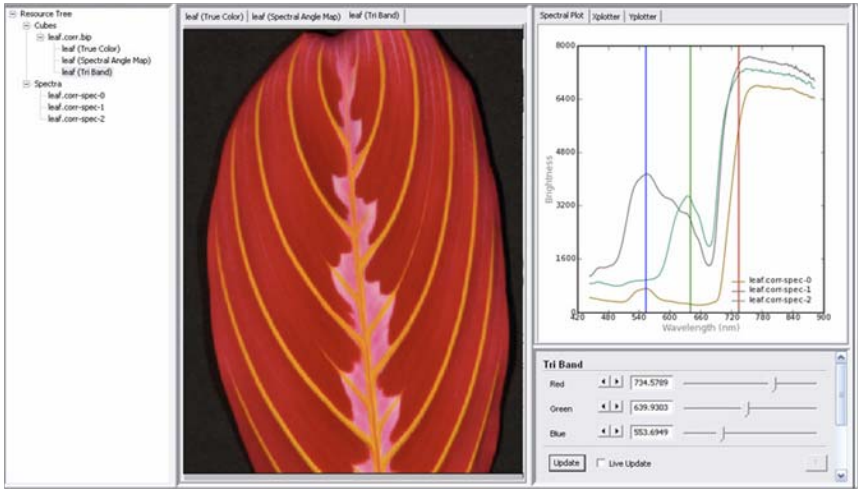
True color



False color highlighting healthy vegetation



Hay field aerial image



Screenshot of a leaf “datacube”

Courtesy of Resonon, Inc.

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Data Reduction Features Overview

Tools:
- Spectrum Pixel Inspector
- Panning & Zooming
- Rectangle & Freehand ROI Selection
- Rotation and Flipping

File Formats:
- Datacube: BIL, BIP, BSQ
- Image Export: PNG, JPEG, BMP, ...

Plots:
- Single pixel spectrum
- X axis cross section
- Y axis cross section

Image Acquisition Tools:
- Focus
- Calibration
- Scanning

Image Acquisition Modes:
- Reflectance
- Radiance
- Raw Data

Extendable Plugin Architecture:
- Python Interpreter Console
- Plugin Templates

RGB Renderings:
- True Color
- Near Infrared
- By Band Number
- By Band Wavelength
- By Band Name

Gray scale Renderings:
- By Band Number
- By Band Wavelength
- By Band Name

Datacube Manipulations:
- Bin
- Crop
- Correct
- Convert
- Subtract
- Multiply
- CIE Colorspace conversion
- Principal Component Analysis (PCA)

Datacube Classification:
- Euclidian Distance
- Spectral Angle Mapper (SAM)
- Quadratic Discriminant Analysis (QDA)
- Spectral Unmixing
- Many Agricultural Classifications

Types of UASs

- **Wide range of sizes and COT**
  - DoD vehicles too expensive, too big a payload!
  - Small systems are at the edge of utility
    - Flight times of 6-8 hrs.
    - 20 mile range
  - Many fly at 100 mph
    - Suitable for agricultural and forestry uses
  - Must have a pilot
    - But can handle multiple UASs
  - A center will guide efforts

NORTHROP GRUMMAN GLOBAL HAWK (USAF)

Dragon UAV 25# p/l

MQ-1 PREDATOR WITH HELLFIRES
image copyright Richard Seaman (http://www.richard-seaman.com)

Manta UAV 15# p/l

Phase 1 UAS Program

- **Phase 1 is estimated to take 18 months**
  - Integrate sensor package
    - Resonon Hyperspectral camera
      - 400 to 900 nm wavelength (240 bands, 80 usually recorded)
      - 5 generally sufficient for assessing plant health (depending on plant)
    - LIDAR scanner for terrain (helps in interpreting hyperspectral data)
    - Infrared sensor
      - 1000 to 1700 nm wavelength
    - GPS
      - Position and Time
    - Data turnaround in 48 hours
  - Design and integrate single string UAS avionics system
    - Fly proof of concept on fixed wing aircraft
  - Montana Test Site
    - But other sites possible
    - Collaboration with Auburn invited (expected!)
      - Agriculture and Forestry specifics

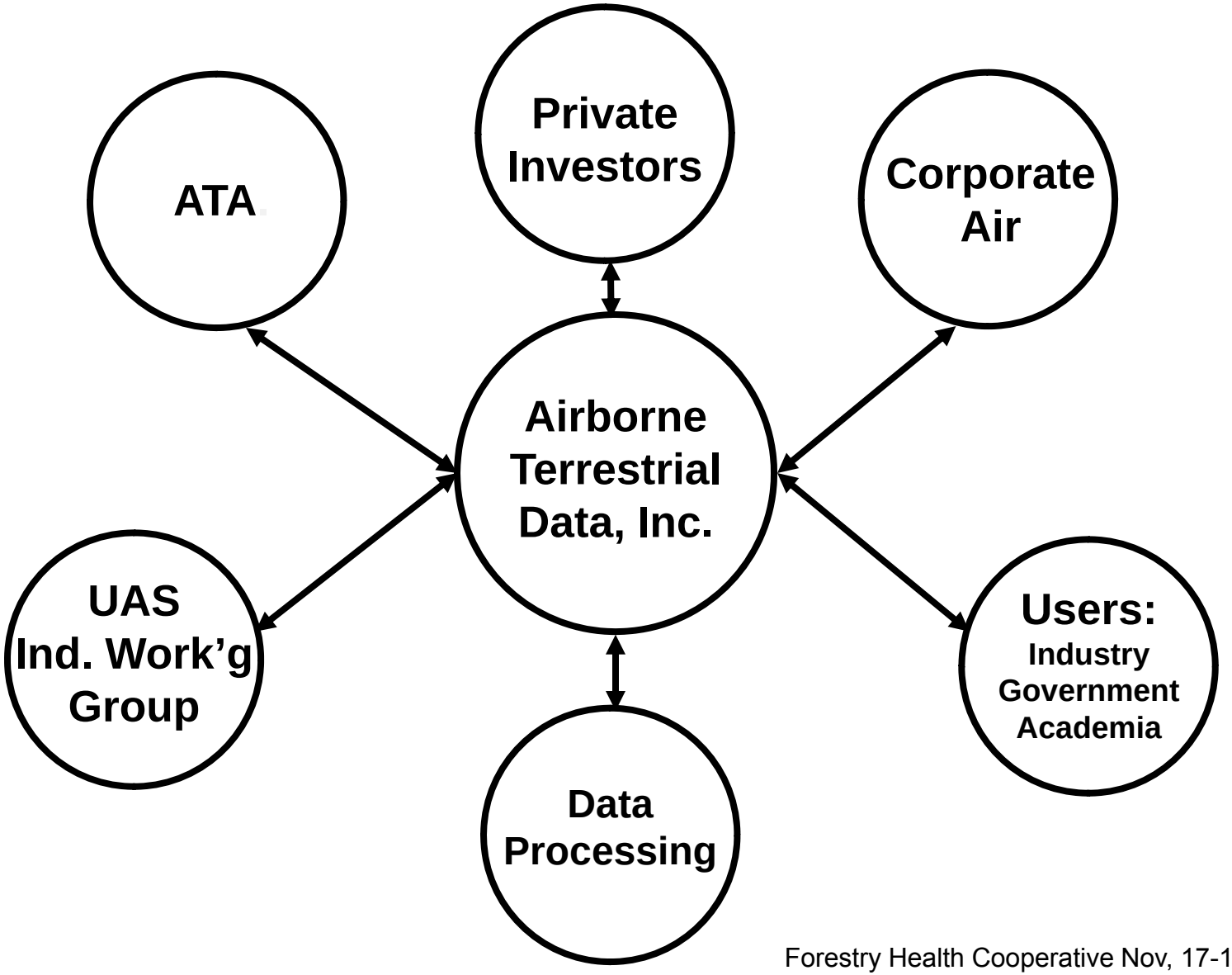
Input Desired from Users

- **Help to define needs**
  - Forestry/Agriculture
  - Spectral bands and resolution
  - Acreage to be covered
    - We know this is very large
    - Will impact the vehicle size and range
  - What types of infestations are of interest
    - Pine bark beetles?
    - Others
- **We've talked to agriculture experts at Auburn for their inputs**
  - Price/value
  - Timeliness
  - Accuracy
  - etc.

Agricultural Inputs

- **What would they be willing to pay?**
  - $3-$10/acre for row crops like cotton, peanuts, soybeans, etc., but double that ($6-$20) for specialty crops like fruits and vegetables
- **What resolution do they need?**
  - 0.5m at least, more is better (must be at a row level (30"-40"). Field truth is necessary
- **Timeliness is a critical issue:**
  - Can't wait more than a couple of days for the results
  - Data processing has been a major bottleneck in the past
  - Cloud cover that prevents a flight is an issue (sensor types)
- **Types of agricultural information desired:**
  - Soil moisture content (e.g. water)
  - Fertility regimen (several measures)
  - Plant growth
  - Insect/viral/fungal infections
- **Data processing:**
  - Background subtraction
  - Ground truth validation
  - Features extraction
- **Determining yield and maximizing yield determines farmers' profitability**
  - Directly applies to forestry needs as well

Industry Participation



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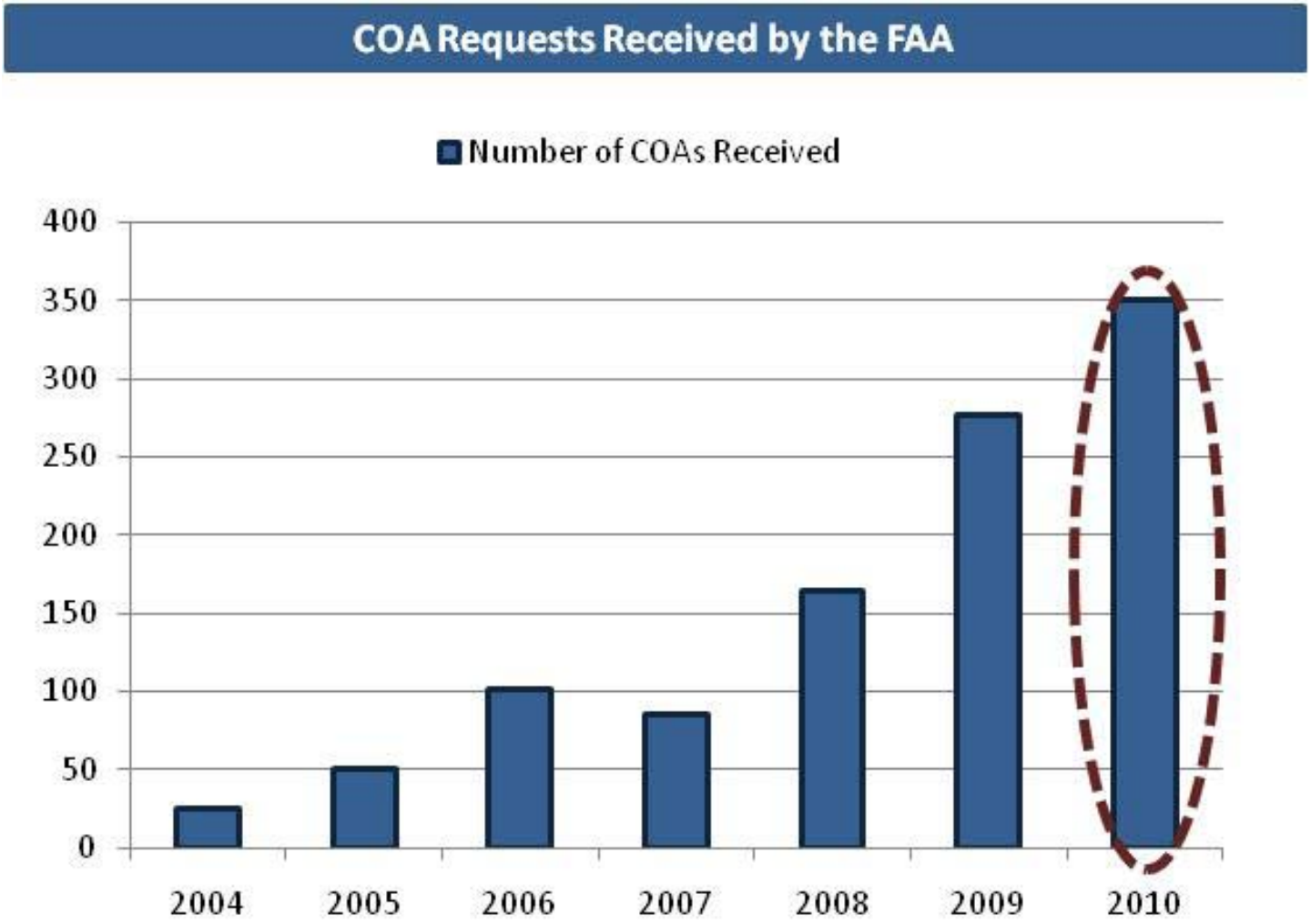
National Airspace Issue

- **Integration of UAS into the National Airspace is a Safety Issue**
  - FAA prohibits UAS commercial flights
  - FAA requires Certificate of Authorization (COA) for each kind of UAS Flight
- **The number of COA's are growing each year (next side)**
  - Takes up to 6 months to process one COA
- **The UAS Airspace Issue is world wide**
  - Europe established a working group
  - Australia has integrated a UAS Airspace strategy
- **The solution of the National Airspace Issue enables commercial UAS markets**
  - Estimated US UAS commercial markets will be $100 B/y (Department of Commerce)

Source: Association Unmanned Vehicle Systems International 2010

Certificate of Authorization (COA)



Source: Association Unmanned Vehicle Systems International 2010

FAA and UAS Markets

Actions Underway

- **Montana State Government**
  - Provide Funding for Start-up
  - Provide Funding for Phase I Program
- **Congressional Delegation – Ongoing Effort**
  - Assure FAA UAS Center of Excellence Located in Montana
  - Support the Establishment of a NASA UAS Technology Test Center in Montana
  - Identify & Facilitate Federal Funding for Montana UAS Programs Through Federal Grants to State Universities
- **UAS Industry Working Group - Ongoing**
  - Provide technical and management support
  - Provide inputs/needs for targeted commercial areas
    - Forestry and agriculture
    - Seeking direct benefit to Alabama!

Summary

- **Advanced Technology Associates and Corporate Air have started a campaign to establish a major UAS center in Montana**
  - Focus is on affordability and commercial applications
  - Forestry and Agriculture
    - Due to the huge impact pests, etc. have on profitability
  - Many unknowns yet
    - Cost effectiveness, customer base, diverse requirements
    - Airframe, data acquisition and processing
    - But have expert companies involved
  - Need user needs and specifics
    - Pine bark beetles are a major target
    - Your help is needed to help establish sensing requirements/timeliness
    - Price of information, timeliness, value?
- **Significant issues need to be overcome**
  - National airspace/FAA
  - Safety, etc…

Acknowledgements

- **Many thanks to David Scruggs and Grant Williams (ATA) for providing the programmatic details of the Montana UAS Center project and plans**