Fall 2005: ESD.85 Seminar on Emerging Technologies

Integrating UAVs into National Airspace (*Safely*)

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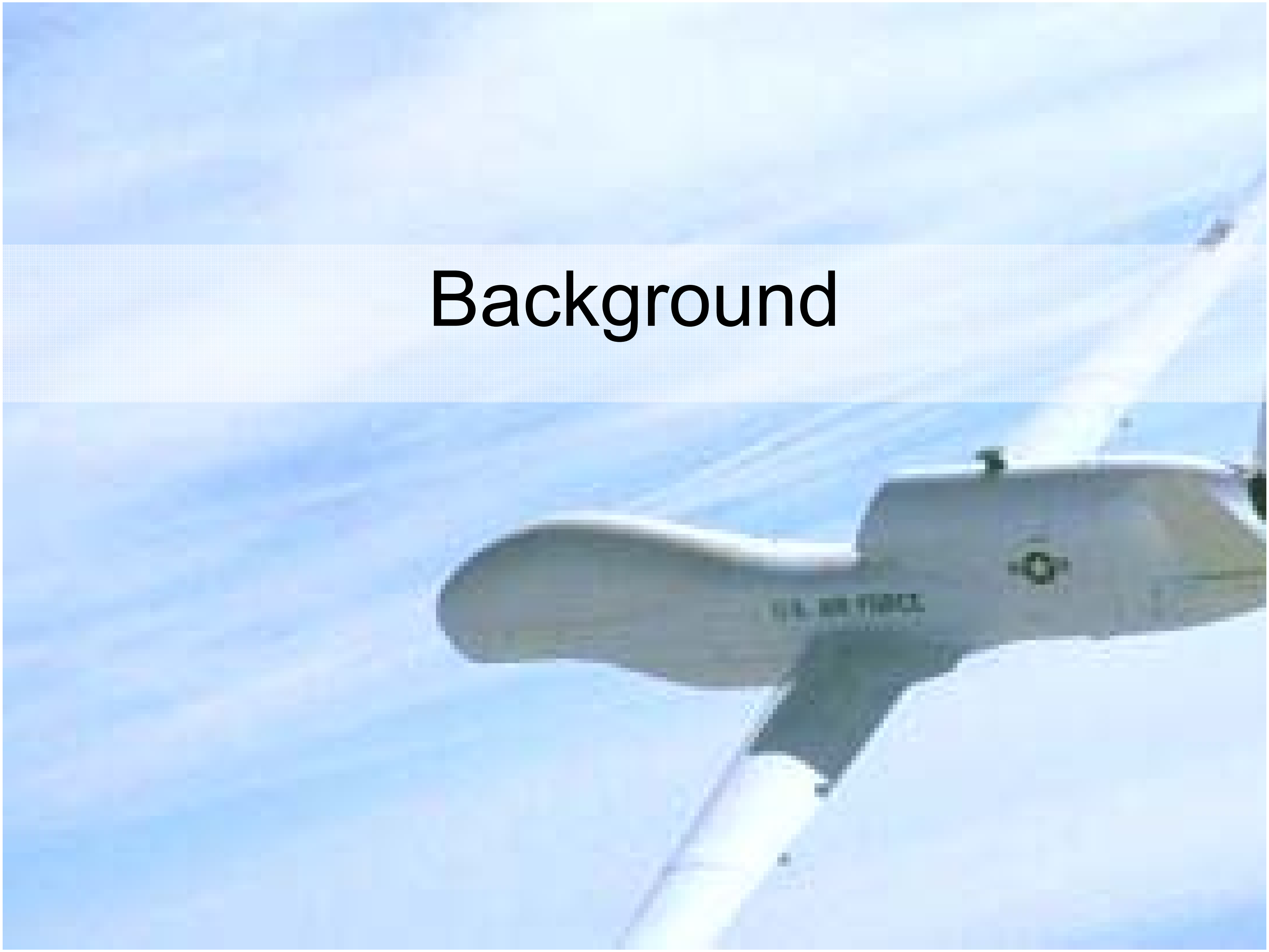
Background



Definition of a UAV

- Unmanned Aerial Vehicle
- Definition from DoD Dictionary (Joint Publication 1-02):

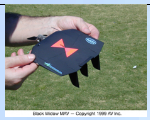
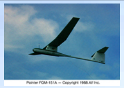
  A powered aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload.

Characteristics of UAVs

- UAVs originally developed by military
- Operators
  - Remotely controlled
  - Autonomous
- Advantages
  - Ultra-long endurance
  - High-risk missions
- Disadvantages
  - No human operator on board; less able to react to non-standard situations

Classes of UAVs

Table 6: Summary of Vehicle Classes

Class	Representative Aircraft	Mass Range	Operating Area	Operating Altitudes
Micro		Less than 2 lb	Local	Near-surface to 500 ft
Mini		2 to 30 lb	Local	100 to 10,000 ft
Tactical		30 to 1,000 lb	Regional	1,500 to 18,000 ft
MALE	Photo removed for copyright reasons.	1,000 to 30,000 lb	Regional/ National	18,000 ft to FL 600
HALE			Regional/ National / International	Above FL 600
Heavy*	Photo removed for copyright reasons.	Over 30,000 lb	National / International	18,0000 ft to FL 450

Courtesy of AeroVironment Inc. Used with permission.

Courtesy of AeroVironment Inc. Used with permission.

Photo Courtesy of AAI Corporation. Used with permission.

Source: Weibel, R. "Safety Considerations for Operations of UAV in the NAS." MIT Master's thesis, Prof. J. Hansman, advisor: 2005

UAV Applications

- Military: High risk missions and surveillance
- Non-military government use:
  - Homeland Security, Border Patrol
  - Tactical Law Enforcement
  - Scientific uses, e.g. collecting data over Mt. St. Helen
  - Maritime Surveillance
- Commercial
  - Stratospheric Telecommunications Airship
  - High-Altitude Imagery
  - Environmental Sensing, e.g. agriculture
  - Traffic Reporting
  - Film industry, e.g. *Winged Migration*

National Airspace System (NAS)

- A web of communication, navigation, surveillance systems that ensures safe flight
- Existing NAS: (*talk to Alex*)
  - – Evolved for manned operations
  - – Lack of regulations for UAVs
- Future NAS: Expected to change significantly
  - – Capacity, environmental, safety, increasing autonomy, air traffic control
  - – accommodate UAVs
- **Question: How to integrate UAVs safely into the NAS?**

Certificate of Authorization (COA)

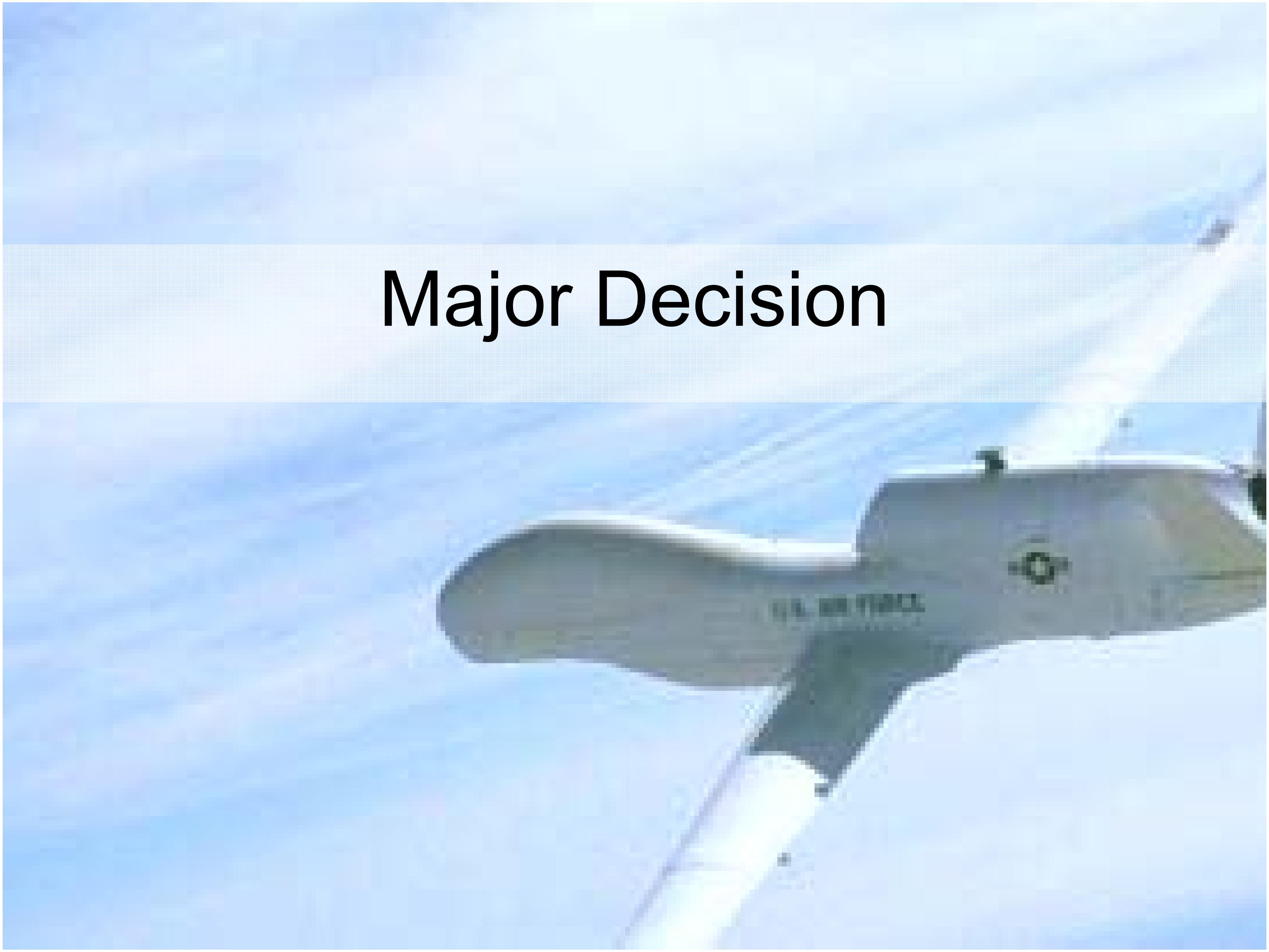
- Originally utilized for non-routine military UAV operation in civil space
- Current approval process jointly developed by DOD and FAA, 1999
  - Case-by-case safety evaluation
  - Weeks to months
  - E.g. radar coverage and/or chase plane
  - Cumbersome, incapable of sustaining high volume of UAV requests

COA: Global Hawk

Fall 2003, the DOD and FAA, developed a "national COA" specifically for the Global Hawk UAV

- Single approval for national flights
- Approval time reduced to 1 week
- Still not a long-term solution for integrating UAV into NAS

Major Decision



Access 5: Who? Why?

- Collaboration between multiple stakeholders
  - Sponsored by NASA & Industry (UNITE)
  - Participation by FAA, DOD, DHS, NOAA
- May 2004 -- Replace COA with streamlined regulatory process to fly UAVs in NAS "routinely, safely, and reliably"
- Focus on technology, regulations, policies and infrastructure to achieve aim

Access 5: What?

Focus on HALE (High Altitude Long Endurance)

- Safest initial introduction amongst classes of UAVs
- Mature system, operate above air traffic
  - Fly above Flight Level 180 (18000ft)
  - Fly for 24 hours

Access 5: How?

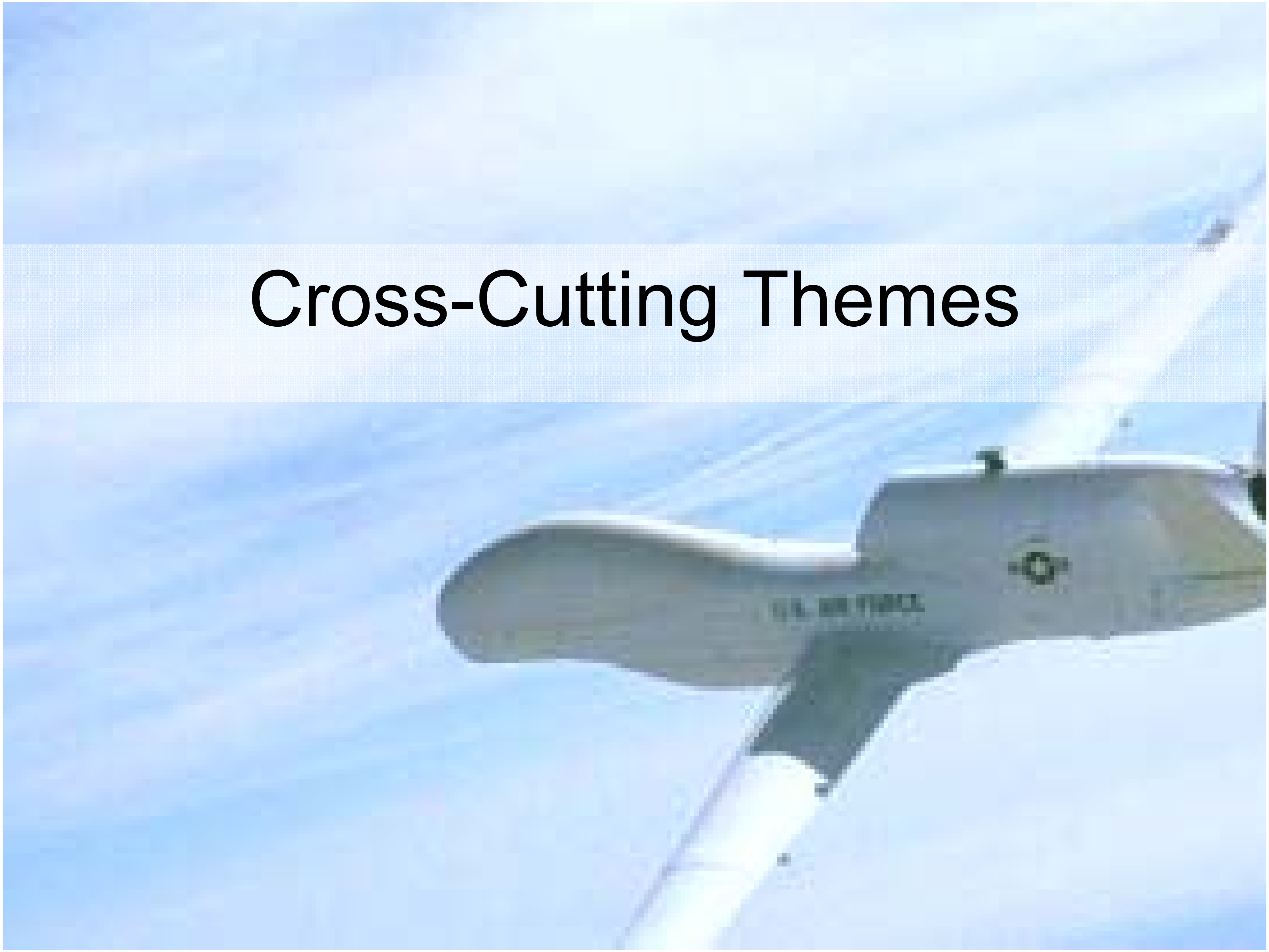
Four staged progressive approach

1. HALE UAS above Flight Level 430 (43,000 feet)
2. HALE UAS above Flight Level 180 (18,000 feet)
3. UAS designated airports with emergency landings
4. UAS designated airports, including emergency landings (i.e., true "file-and-fly")

Dealing with Uncertainties

- Access 5 is tasked with answering the question: “How to integrate UAVs safely into the NAS?”
  - Technical Uncertainties – safety, infrastructure
  - Social Uncertainties (?)
- Different plans to test the integration via the incremental staged approach

Cross-Cutting Themes



Interests represented in policy process

- Government
  - NASA: potential future benefits
  - DOD: prevent duplication of efforts (flight testing, technology leveraging, information sharing)
  - FAA: technical advice and coordination
  - DHS, NOAA
- Industry (HALE UAS Manufacturers)
- Not represented
  - Pilots & Airlines, ATC, Public

Distribution of *future* costs and benefits

- Who takes on the *future* benefits?
  - Everyone in Access 5
- Who bears the *future* costs?
  - None in Access 5
    - Flying Public, Public in the Vicinity
    - Airlines, Pilots
    - ATCs : increased workload
    - Maybe indirectly represented by the FAA (?)

What are the *future* costs?

- Safety: collisions
- Financial: increasing capacity, integration into the NAS, liability
- Operational: ATC -- workload increase, traffic management, congestion
- Environmental: noise, pollution

Coping with uncertainty

- Uncertainty: safety of UAVs into NAS?
- Precautionary principle
  - No integration of UAVs
  - Strict regulations e.g. Certificate of Authorizations
- Testing (trial & errors)/ Staged Approach
  - Global Hawk
- Access 5: Access to complete information before making decisions
  - Every stakeholder involved UAVs and NAS (except the Airlines, NATCA)
  - Technical, infrastructure information

New research to address uncertainties

- Technical
  - Command, Control and Communications
  - Sense & Avoid
    - TCAS on UAVs e.g. Global Hawk
    - Sensors and radars
    - Visual Flight Rules (VFR) vs. Instrument Flight Rules (IFR)
- Who controls?
  - Autonomous
    - No intervention, ability to replan according to environment
  - Remote controlled by a pilot
    - Data link: Latency and bandwidth limitations

Determining acceptable risk levels

- Hasn't been determined yet
- Things to consider in setting minimum separation standards and risk tolerance:
  - Classes of UAVs
  - Level of autonomous control of UAVs
  - UAV-on-UAV vs. UAV-on-Manned
  - Region/ locality
  - Type of payloads

Political, economic, and social influences

Political/ Social

- Safety: err on side of caution, Type II error (Miss)
  - Organizational, e.g. FAA
  - Sense & Avoid technologies
- Liability & Jurisdiction
  - FAA: *"Our mission is to provide the safest, most efficient aerospace system in the world."*
  - UAV Manufacturers
- Incentive structure

Political, economic, and social influences

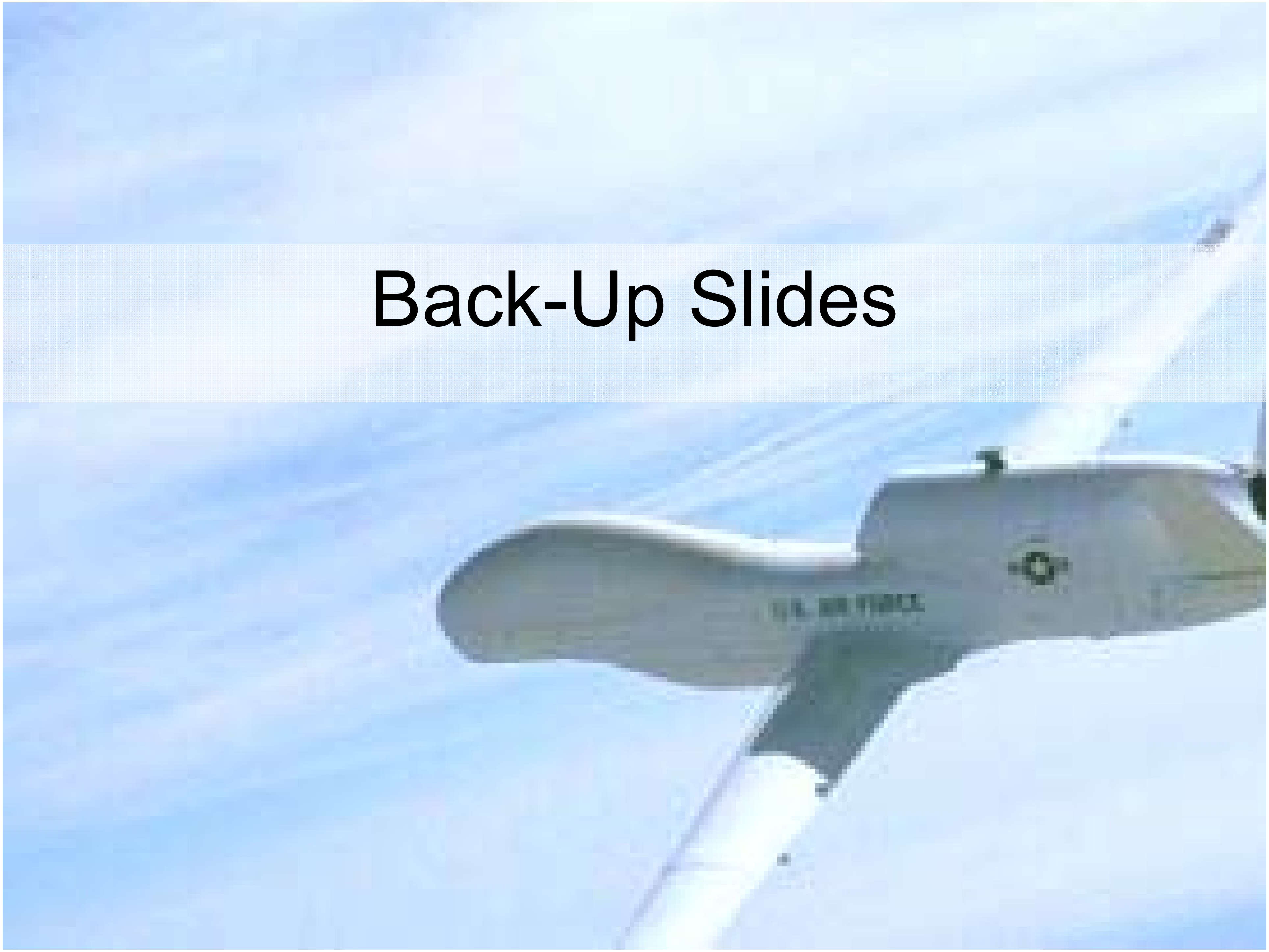
Economic

- Industry (Manufacturers), Stakeholders
- NASA
  - bear 75% of Access 5 costs
    - 25% from industry
  - $103 million planned until FY09 for steps1&2 (Flight Level >180)
    - same funding percentages will apply to future years of the Access 5 project, estimated costs of $360 million
  - Mission expansion (?)
  - For future benefits (?)

Our Questions

- Alternative approaches than Access 5's plan?
- Implementation problems and over-optimism
- Why NASA funded Access 5?
  - Future benefits outweigh current costs (?)
  - Turf expansion/ hedging bets on endangered mission (?)
  - Decision making: Allison's Model 3
- Why did new NASA Administrator cancel all funding for Access 5 in September 2005?
  - Organizational (?)
  - "inappropriate for NASA to fund private industry"
  - NOAA was invited along "for the ride"
  - Plan of Access 5 not working (?)

Back-Up Slides



Levels of Autonomous Control of UAVs

Category of Vehicle Control	Description
Autonomous & Adaptive	The UAV is controlled completely by UAV onboard systems without intervention by an operator or use of a ground station. The UAV has the ability to replan during the flight to account for changes in the environment or new objectives. The UAV may also have the capability to communicate with other controllers in the system.
Monitored	The UAV operates autonomously, while an operator monitors feedback from the UAV. The operator does not have the ability to control the UAV, but could potentially take control actions through other actors in the system.
Supervisory	Low level control is executed by the UAV systems onboard the UAV or ground station. The operator remains engaged in the control loop executing higher level control of the UAV's trajectory or state.
Autonomous & Non-Adaptive	The UAV has the ability to execute pre-programmed actions without input from an operator, but does not have the ability to change the plan during flight or adapt to external disturbances.
Direct	The operator directly controls the UAV control surfaces, mediated by the link between the UAV and ground station

Source: Safety Considerations for Operation of Different Classes of Unmanned Aerial Vehicles in the National Airspace System Weibel R., June 2005

Other Government/ Industry Initiatives

(Other than Access 5)

- American Society of Testing Materials
- Radio Technical Commission for Aeronautics
- UNITE
- International
  - JAA/ EuroControl
  - UAV Safety Issues for Civil Operations

U.S. and the world

- U.S. is leading UAV development in terms of size, variety and sophistication
- U.S. earliest advocate for gaining access to civil airspace
- Other countries with significant UAV capabilities
  - Israel, Japan, South Korea, European (France, England, Germany, Sweden), Australia

Sources of Traffic Surveillance

- ATC Ground-Based Surveillance
- Operator Ground-Based Surveillance
- Sight
- Onboard (non-cooperative)
- Onboard (cooperative)
- Chase aircraft
- Broadcast
- Visibility

Source: Safety Considerations for Operations of UAV in the NAS, Weibel R., Hansman J., 2005