Research Challenges Associated with Unmanned Aircraft Systems Airspace Integration

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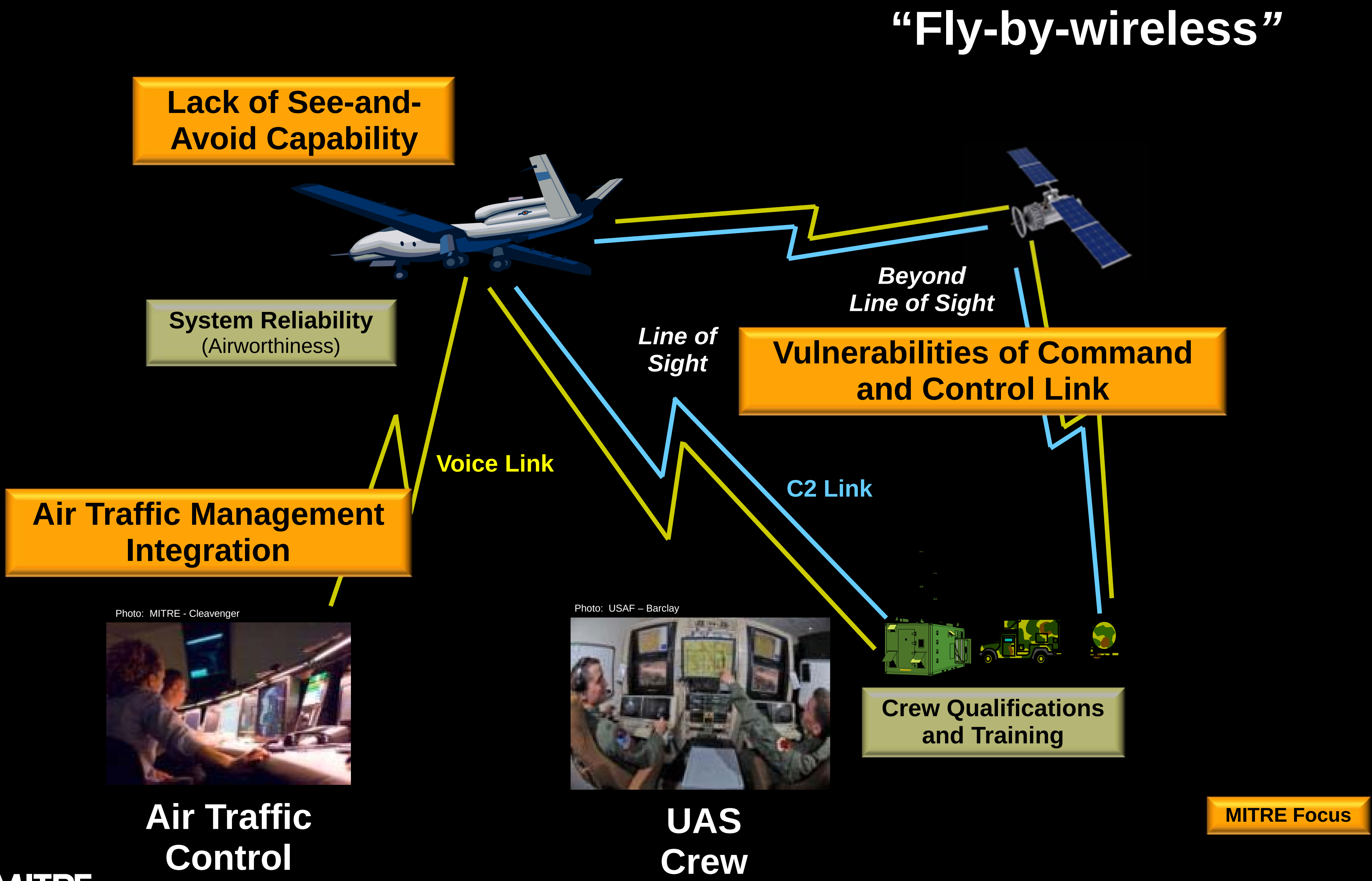
UAS Airspace Integration Vision

UAS regularly operate in non-segregated civil airspace

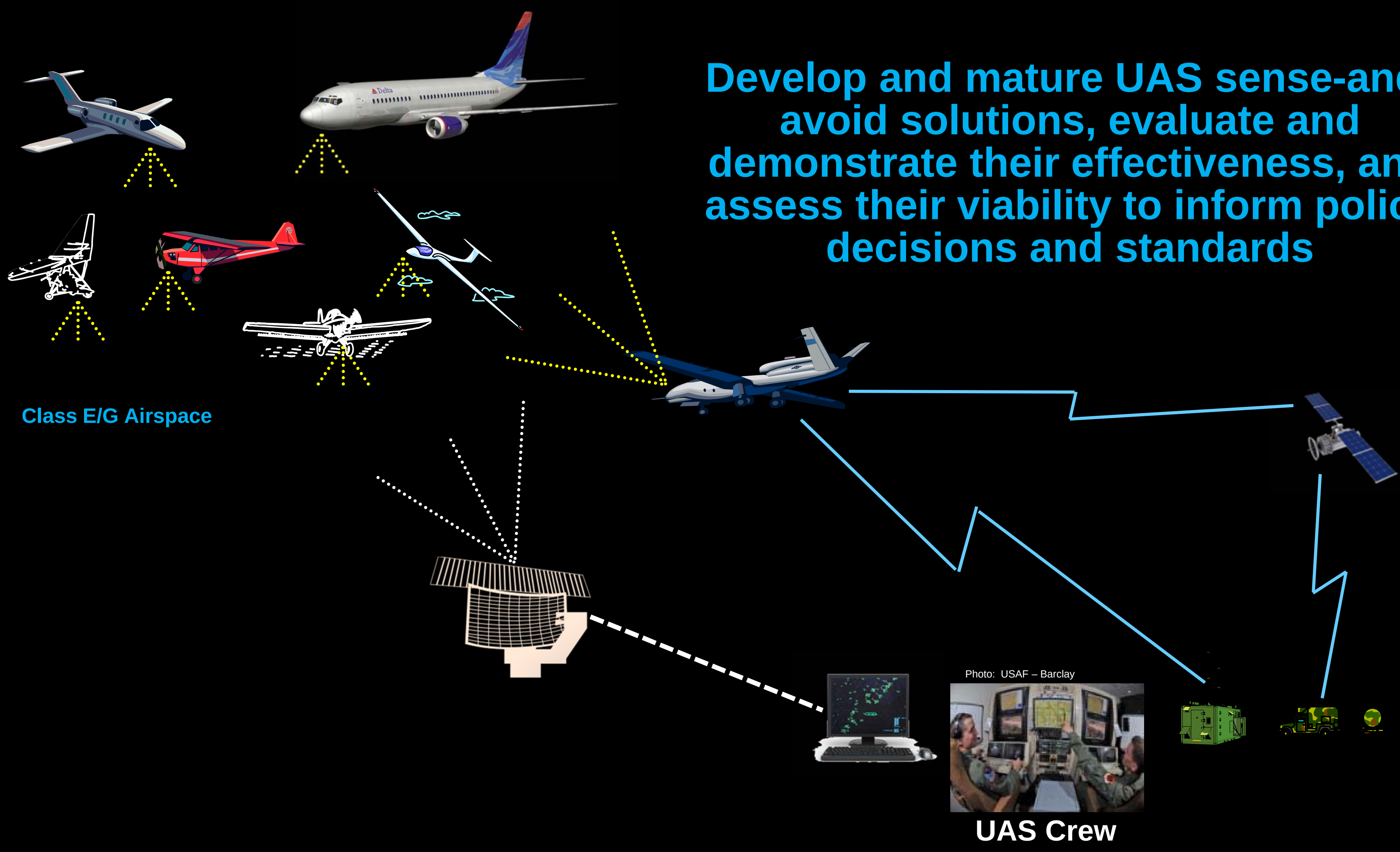
- **Aviation system safety is not degraded**
- **Manned aircraft flows are not disrupted**

Key UAS Integration Challenges



Enable UAS Sense and Avoid

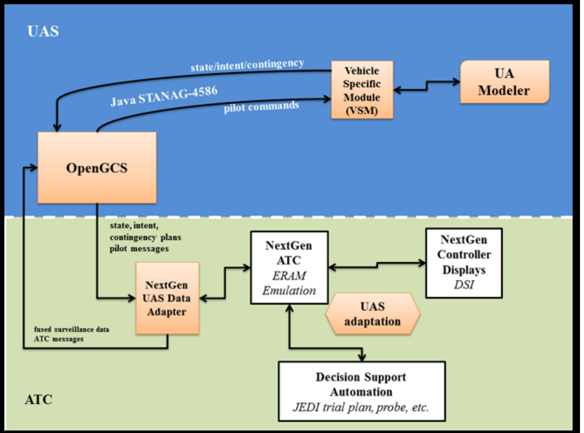
Develop and mature UAS sense-and-avoid solutions, evaluate and demonstrate their effectiveness, and assess their viability to inform policy decisions and standards



Enable UAS C2 & ATM Integration

Photo: USAF

Identify specific operational challenges surrounding UAS command and control failures and integration with air traffic management, propose alternative solutions, and demonstrate their technical feasibility and operational effectiveness



Challenges

- Unintentional or intentional RFI
- Loss/spoofing of C2 link
- Flight path and aircraft performance differences
- Autonomous operations
- Response latencies
- Controller work load

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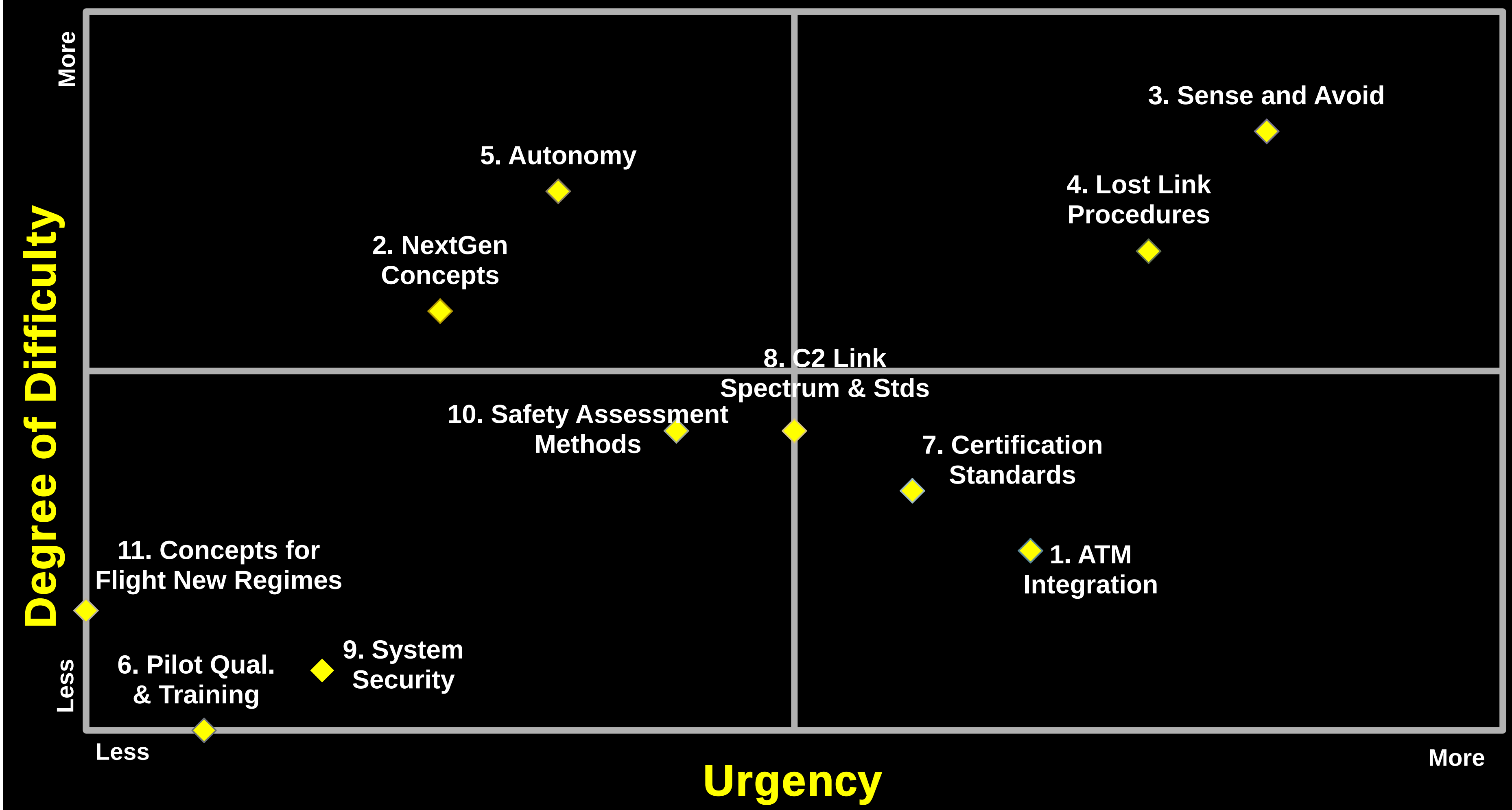
UAS Airspace Integration Research Areas

1. **Air Traffic Management Implications –** What is the impact on air traffic management of routine UAS operations in sectors of varying complexity?
2. **Implications for NextGen Concepts –** How should the NAS evolve in the future towards NextGen to best accommodate UAS capabilities and unique airspace integration requirements?
3. **Mitigations for the Lack of See and Avoid –** What are some alternatives that can safely mitigate the lack of see and avoid?
4. **Standardized Lost Link and other Contingency Procedures –** What are the appropriate standardized procedures for lost link and other flight contingencies and how can their safety effectiveness be demonstrated?
5. **Implications of Autonomy –** What are acceptable levels of autonomy for operations in the NAS?
6. **Training and Pilot Qualifications –** What criteria and standards should the FAA establish for civil certification of UAS pilots and other required crew members?
7. **Equipment Certification –** What criteria and standards should the FAA establish for civil certification of UAS equipment including aircraft, avionics, ground control stations, launch/recovery, and communications equipment?
8. **Command and Control Link –** What are the communications system performance requirements (e.g., range, integrity, availability, latency) of the Command and Control (C2) link?
9. **Airspace Security –** What are the airspace security implications of UAS?
10. **Safety Risk Assessment –** How should safety risk assessment methodologies and criteria be customized for UAS operations?
11. **Flight in Non-Traditional Regimes –** Can the FAA establish new safety and operational requirements for flight in non-traditional regimes (e.g., under bridges, urban canyons, in close proximity to buildings, below tree line)?

Relative Priority - Unvalidated



Urgency: The pressing necessity of when and or what pace this research is conducted. Research from which results are needed immediately would thus be the most urgent.
Degree of Difficulty: The relative complexity and risk associated with the research (not implementation or policy adoption). This should capture the technical risks associated with development efforts, the breadth of the unknowns, and the interaction of technical, operational, and policy issues. The greater the degree of difficulty the more the research would be dependent upon fundamental breakthrough for success. [based upon Mankins, John, *Research & Development Degree of Difficulty (R&D3) - A White Paper*, NASA Office of Space Flight - Advanced Projects Office, March 10, 1998]

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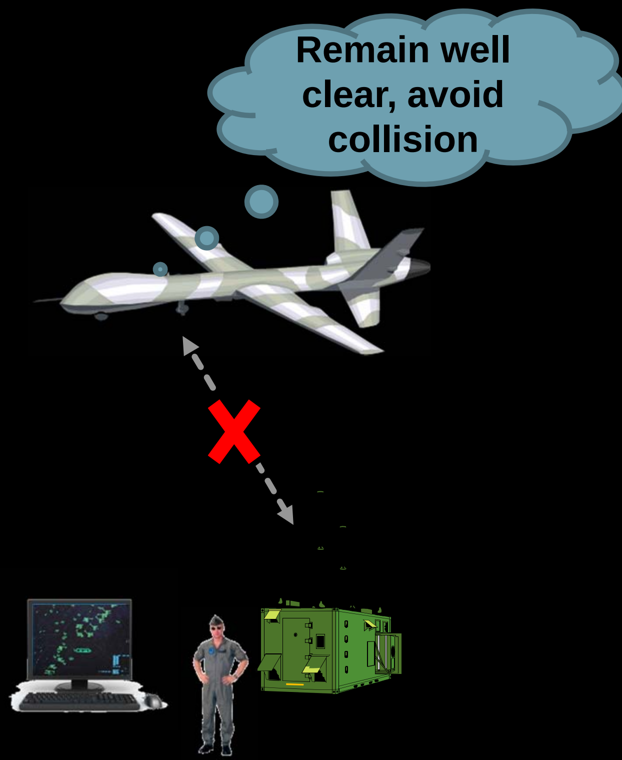
When is Autonomy Needed?



Degrees of Autonomy

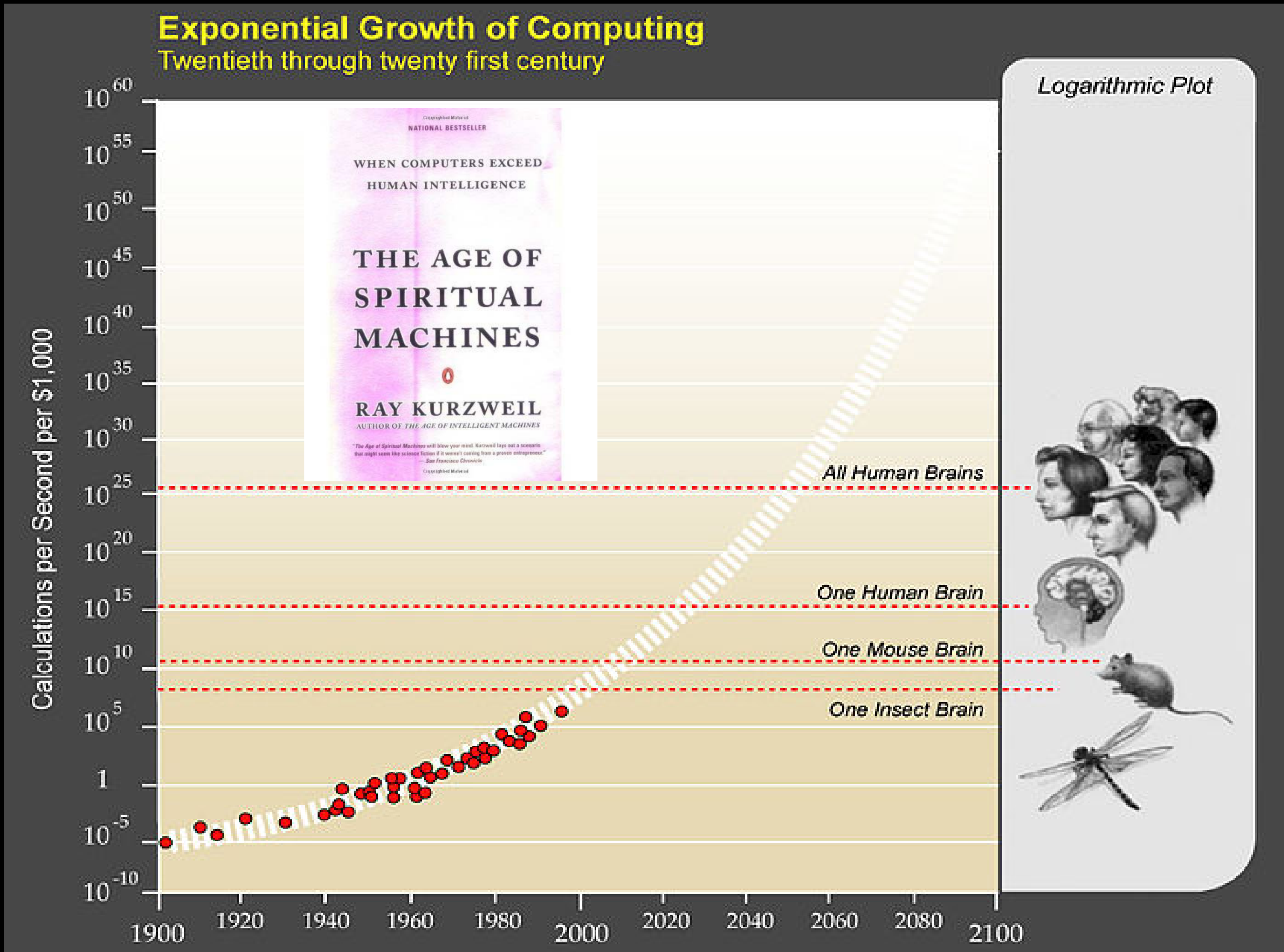
Role of Automation

Role of Human

(1) Human does the whole job, turning over to the computer to implement
(2) Computer helps by determining the options
(3) Computer helps to determine options & suggests one, human need not follow
(4) Computer selects action and human may or may not do it
(5) Computer selects action and implements it if human approves
(6) Computer selects action, informs human in plenty of time to stop it
(7) Computer does whole job and necessarily tells human what it did
(8) Computer does whole job and tells human what it did only if human explicitly asks
(9) Computer does whole job and decides what the human should be told
(10) Computer does the whole job if it decides it should be done, and if so, tells human, if it decides that the human should be told

Thomas Sheridan and William Verplank¸ Human and Computer Control of Undersea Teleoperators, Massachusetts Institute of Technology, Prepared for the Office of Naval Research, July 1978.

Hardware not the Limiting Factor



Ray Kurzweil and Kurzweil Technologies, Inc via Wikipedia

Degrees of Autonomy

Chasm

Human — Supervisory Control[1] — Fully Automatic — Autonomous

Human

- All actions require Pilot intervention
- Automation may alert pilot and suggest courses of action

Supervisory Control[1]

- Automation algorithms determine course of action
- Pilot remains informed and can override as needed

Fully Automatic

- Algorithms respond to input data without human input or possibility of override
- Take predetermined action
- Control Theory - Feedback loops
- Goal seeking - Sense / Act

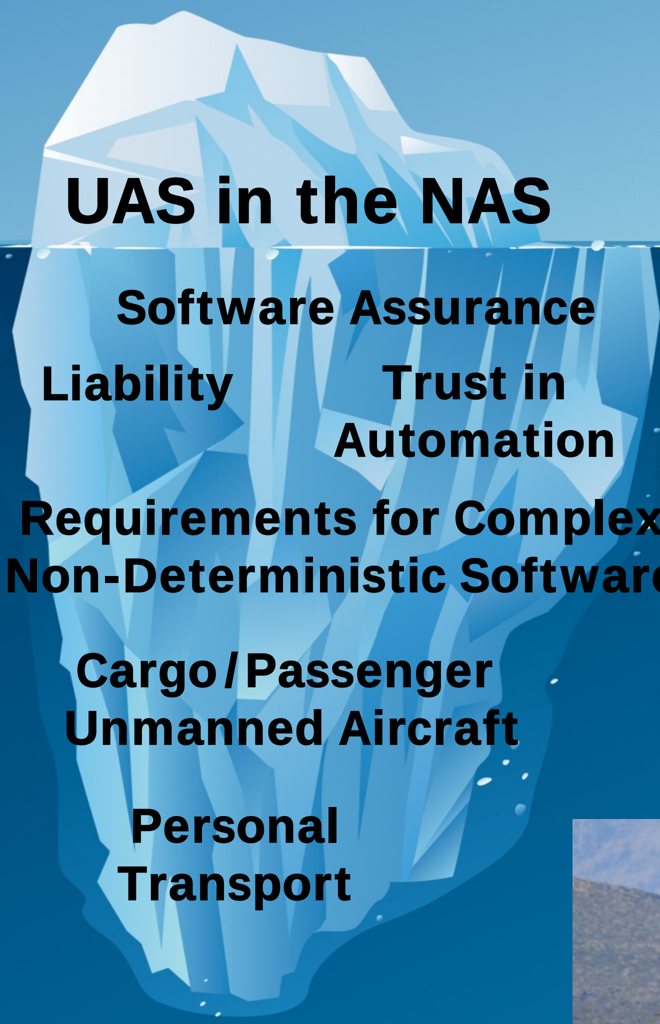
Autonomous

- Non-deterministic inputs
- Judgment
- Emergent behavior
- Perception & Reasoning

1: Charles Billings, 1997, Aviation Automation: The Search for a Human-Centered

Autonomous Flight

- **Enables routine unmanned flight**
- **Improves the safety of all flight**
- **Enables future concepts**



UAS in the NAS

Software Assurance

Liability

Trust in Automation

Requirements for Complex Non-Deterministic Software

Cargo/Passenger Unmanned Aircraft

Personal Transport

U.S. Navy photo Courtesy Northrop Grumman

Images: istockphoto.com

A *Potential* Evolution

Heavy Crew: 4 Pilots - $$$$

today

Light Crew 1: T/O, Transition, & Landing - 2 Pilots, 1 Remote Pilot - $$$

Light Crew 2: T/O, Transition, & Landing - 2 Pilots, PT Remote Pilot - $$$

Single Crew: T/O, Transition, & Landing - 1 Pilots, PT Remote Pilot - $$

Long-Haul Cargo Jumbo

Unmanned: 1 PT Remote Pilot - $

20??

Image: istockphoto.com

The Long-term Need

- Research to help define and determine whether autonomous flight is a goal
  - If so when?
- Research to help cross the chasm between automatic flight and autonomous flight

Image: Andrew Lacher


Thank You
www.arcent.Army.mil (Photo by Petty Officer 1st Class Michael Larson)