Headquarters U.S. Air Force

Integrity - Service - Excellence

Unmanned Systems and HSI… Air Force Lessons Learned

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Colonel Larry Kimm
Director, AF HSI Office
Undersea HSI Symposium
27 July 2010

Overview

- Air Force and Navy Unmanned Systems
  - Human Systems Integration Impacts
    - The commonalities
    - The differences
- Lessons Learned
- AF research findings Navy may use
- Ponderings – What does the future hold?

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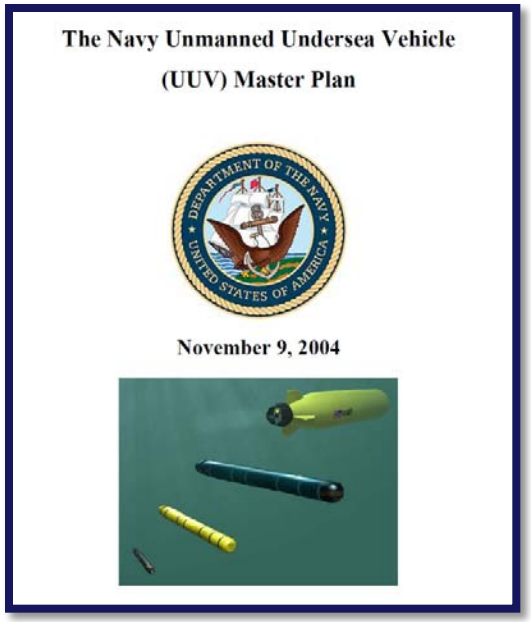
Senior Service Leaders on Unmanned Systems

- **"We will continue to push the UAS envelope ... Unmanned systems are unmanned in name only. While there may be no Airmen on board the actual vehicle, there are indeed airmen involved in every step of the process, including the pilots who operate the vehicle's remote controls and sensors and maintenance personnel."** **(General Fraser, VCSAF, Pentagon News Conference, 23 Jul 2009)**

- **"…Unmanned vehicles need to be as close to their names as possible. Replacing one person in the cockpit or on the bridge with 10 people in the remote control room does not get us towards minimal manning and it is almost ironic if we then call these systems 'unmanned.' …"** **(Admiral Gary Roughead, CNO, Surface Navy Association Symposium, 14 Jan 2009)**

Navy, Unmanned Systems and Human Systems Integration


The Navy Unmanned Undersea Vehicle (UUV) Master Plan

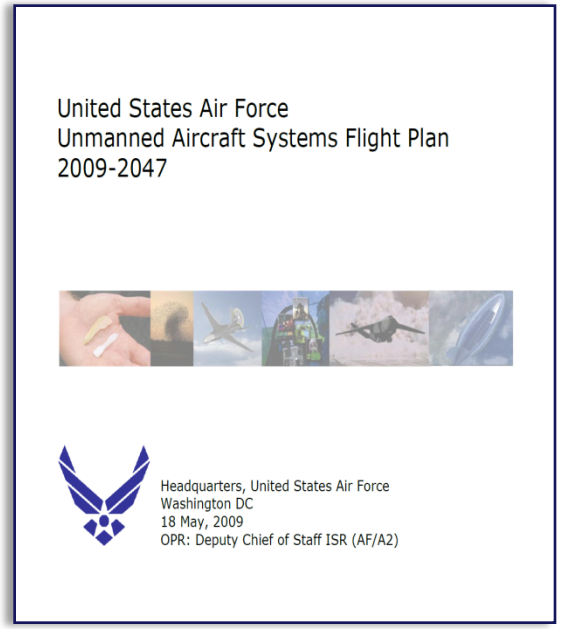
November 9, 2004

5.3.7 Human Systems Integration (HSI)

The product of UUV use is knowledge and data to the warfighter today, and in the future direct actions which aid the warfighter. As a result, the integration of the unmanned system with the "manned" system is paramount. HSI should be addressed as a major part of every UUV program and strategy. A comprehensive strategy for HSI will encompass all of the seven domains: Human Factors Engineering; Personnel; Habitability; Manpower; Training; Environment, Safety and Health; and Survivability. Addressing these factors will be the dominant challenge in the fielding of low cost / COTS UUV systems.

The goal of UUV Program HSI efforts, in conjunction with the NAVSEA HSI Directorate, is to deliver well-engineered and usable systems for Warfighters. Through coordinated and cooperative application of HSI principles, the UUV Programs will meet these objectives, improve Fleet training and readiness, enhance Sailor performance and professional development, and reduce life cycle costs.

Air Force, Unmanned Systems & Human Systems Integration


United States Air Force
Unmanned Aircraft Systems Flight Plan
2009-2047

Headquarters, United States Air Force
Washington DC
18 May, 2009
OPR: Deputy Chief of Staff ISR (AF/A2)

3.6 Human Systems Integration (HSI)
HSI is a disciplined and interactive systems engineering approach to integrate human considerations, including human capabilities and limitations, into system development, design, and life-cycle management. Doing so will improve total system performance and reduce cost of ownership. The major domains of HSI are: manpower, personnel, training, human factors engineering, environment, safety, occupational health, survivability, and habitability (AFI 63-1201).

As our USAF modernizes, UAS will continue to provide new and improved capabilities that will require unique interfaces with other operations, systems, and operators with a wide spectrum of skills and training to operate, maintain, support and sustain these systems and interfaces. Regardless of where the human interfaces occur, or the sophistication of the system and its flight control capability, the ultimate success of the systems will depend on the effectiveness of the human interfaces.

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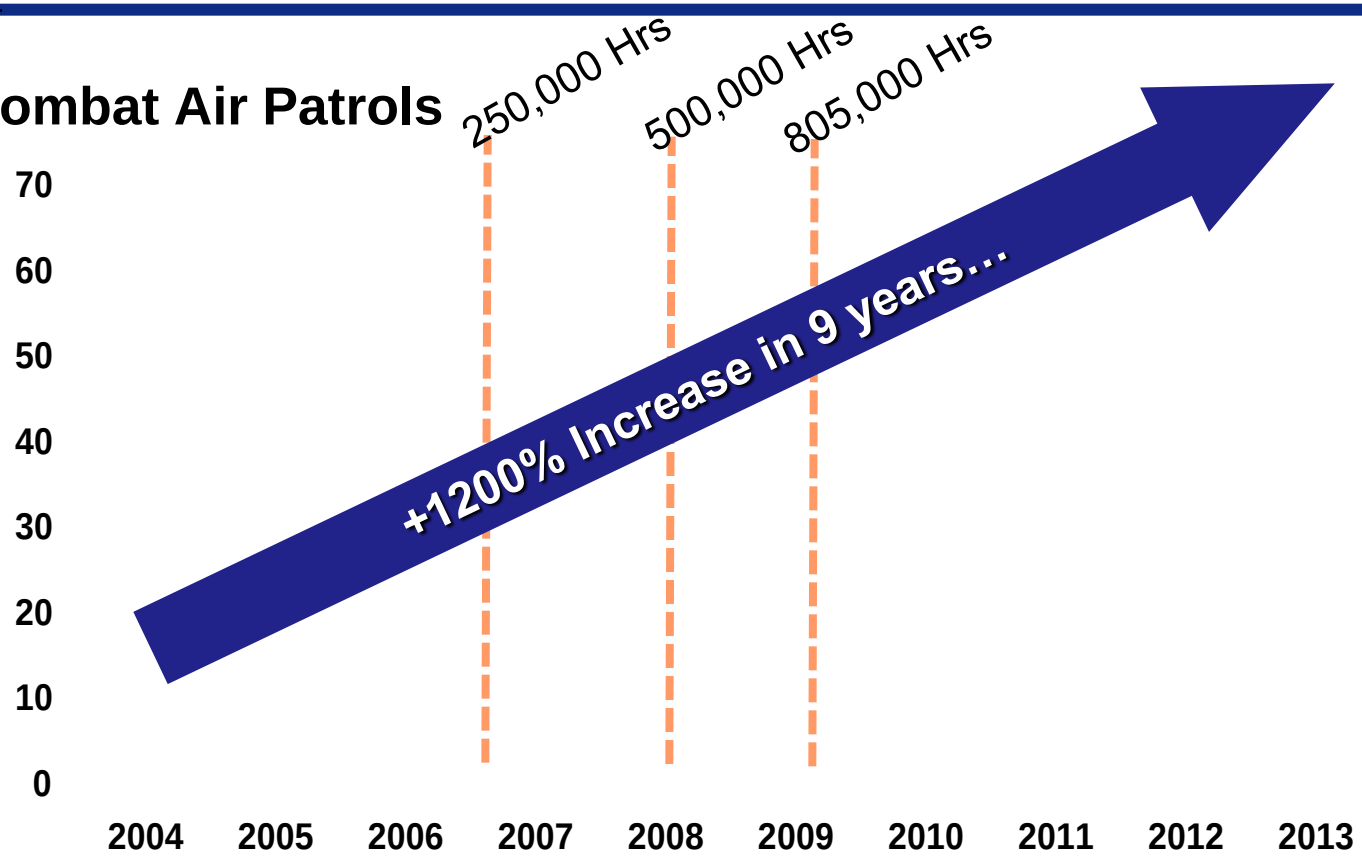
Air Force Growth in RPA

Growth in RPA Combat Air Patrols

- 2004 = 5
- 2005 = 8
- 2006 = 11
- 2007 = 18
- 2008 = 33
- 2009 = 39
- 2011 = 50
- 2013 = 65



Insatiable demand with no defined end state

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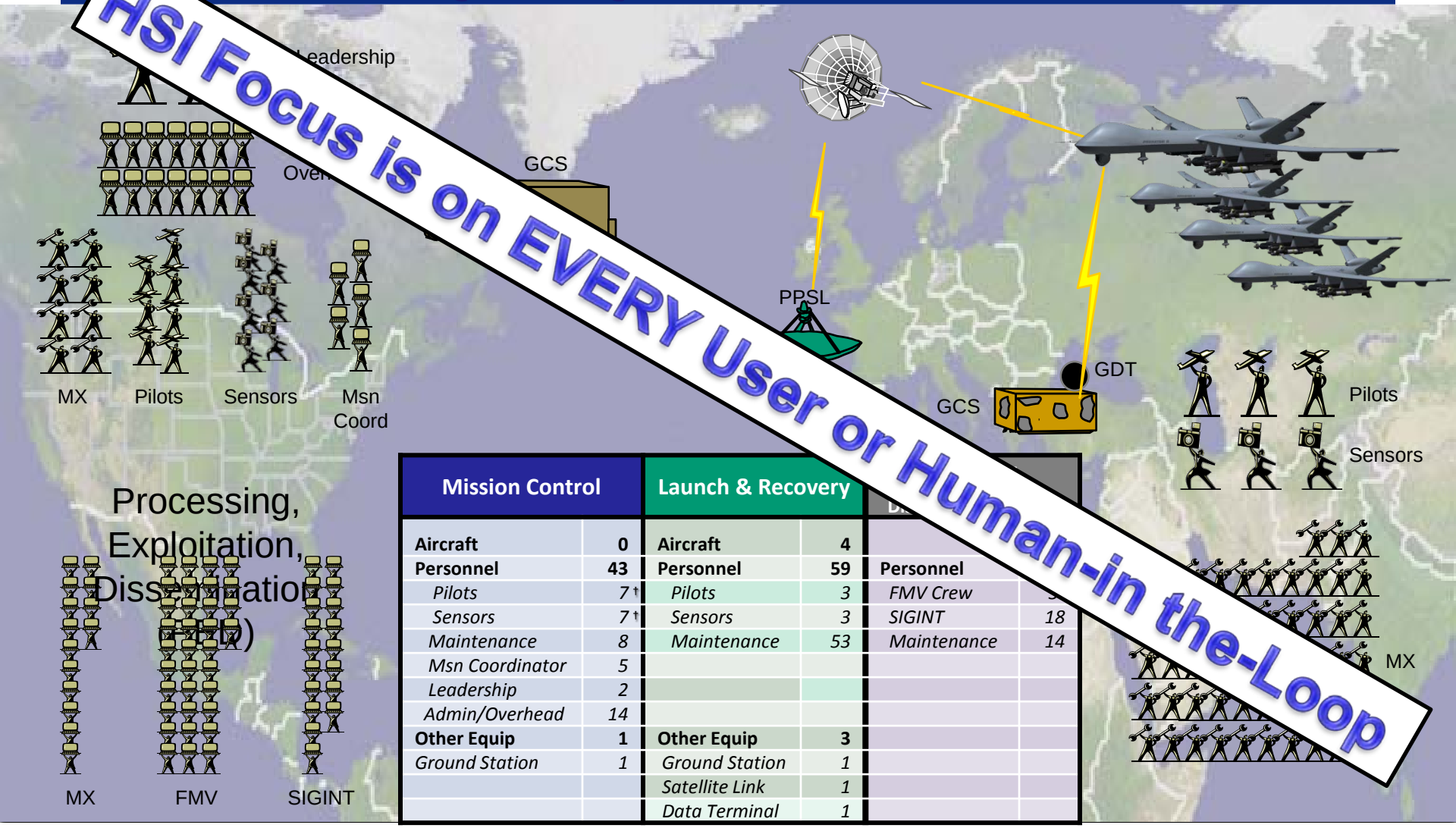
Remotely Piloted Aircraft:

MQ-1/MQ-9 CAP=168 Total Personnel

HSI Focus is on EVERY User or Human-in the-Loop



Mission Control		Launch & Recovery		Di	
Aircraft	**0**	**Aircraft**	**4**		
Personnel	**43**	**Personnel**	**59**	**Personnel**	
Pilots	*7 †*	*Pilots*	*3*	*FMV Crew*	
Sensors	*7 †*	*Sensors*	*3*	*SIGINT*	*18*
Maintenance	*8*	*Maintenance*	*53*	*Maintenance*	*14*
Msn Coordinator	*5*				
Leadership	*2*				
Admin/Overhead	*14*				
Other Equip	**1**	**Other Equip**	**3**		
Ground Station	*1*	*Ground Station*	*1*		
		Satellite Link	*1*		
		Data Terminal	*1*		

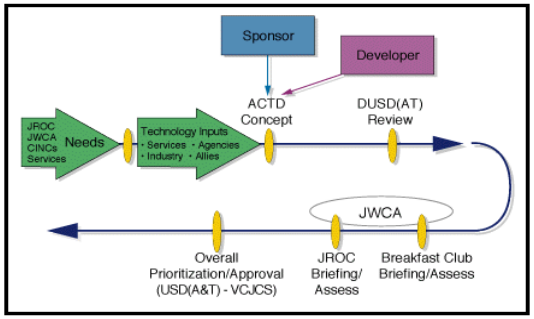
* Additional CAPs co-located require ~80% less MX, ops/PED personnel remain the same
† Surge numbers, steady state = 10 each
‡ Does not include backshop Personnel

Predator – ACTD / Rapid Acquisition Differences

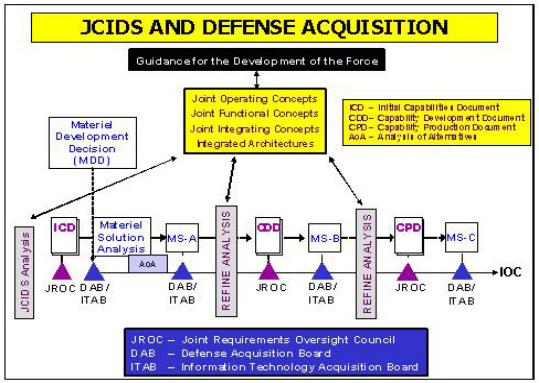
To ensure the human is considered early in the UAS decision matrix, HSI will be:

1. Applied in the front end analyses
2. Addressed in the DOTMLPF analytical solution process
3. A key consideration in Analysis of Alternatives (AoA) planning and execution
4. Used to develop and support source selection criteria and weighting for contracted development efforts
5. Used to conduct proactive domain trade-offs to facilitate total system performance
6. Assessed throughout the system life-cycle, particularly in Test and Evaluation with measurable and testable requirements

The USAF Human Systems Integration Office and AFRL 711th Human Performance Wing will provide the organizational expertise for USAF HSI. These organizations will assist UAS teams in conducting HSI analyses and provide SME support to HPTs, IPTs, working groups, and program offices.



Versus



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Pocket Guide for HSI in Requirements

U.S. AIR FORCE

HUMAN SYSTEMS INTEGRATION OFFICE

HUMAN SYSTEMS INTEGRATION REQUIREMENTS POCKET GUIDE

SEPTEMBER 2009

Explains how HSI fits into JCIDS:

- Considerations when writing JCIDS docs
- DOs and DON'Ts
- Examples
- Key Words Reference Matrix
- Key Terms
- POCs and References

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HSI in the Requirements Process

	2009 - 2010
ANALYSES SUPPORT	• 2 CBAs • 4 AoAs • Good working relationship with OAS
HPT SUPPORT	34
DOCUMENT STAFFING	• >226 docs • >98% accept rate
AFROC	• Advisor to AFROC • HSI Endorsement included as part of SAF/AQ Certification
RMCT CERTIFICATION	100%
HSI REQTS TOOLS	*HSI Requirements Pocket Guide*
HSI REQTS PROCESSES	• Dissemination • Review & Comment • Tracking • Endorsement

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Example: HSI Insertions in Global Hawk CDD

Domain	Comment	A/P/R
HFE **Safety** **Personnel** **Training** **Habitability**	All support equipment for repair and maintenance must be ergonomic and safe in design to eliminate personal injury of individuals….must be human friendly to allow ease of operation and maintenance	Accepted
HFE **Safety** **Personnel** **Training**	All technical data must be easy to read and understand to allow for ease of maintenance and operation and to avoid mistakes.	Accepted
HSI – All Domains	In order to maximize effectiveness, design and development must consider and implement the domains of HSI (manpower, personnel, training, ESOH, HFE and survivability). Through application of HSI domains, capabilities will be optimized in total system performance resulting in reduced life cycle costs.	Partial
ESOH **Safety** **HFE**	All personnel shall be protected against environmental hazards. Identified environmental, safety and health risks will be eliminated, minimized or controlled to acceptable levels within cost, schedule and performance constraints.	Partial

Sampling of Air Force Unmanned Systems HSI Challenges

HSI Domain	Challenge
Personnel	**Career paths and advocacy for unmanned vehicle operators**
All HSI Domains, especially Personnel, Training, HFE and Safety	**Unmanned systems historically fielded at times without going through a full vetting in developmental/operational testing →Suboptimal design, decreased performance, increased costs**
All HSI Domains	**New system configurations once fielded leads to added costs and burdens on acquisition and logistics systems**

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Unmanned Systems and Unique Interface Issues

- For manned aircraft systems, maneuverability is characterized by ability to withstand G Forces -- human body can only sustain 9 Gs
  - Technology is the only limiting factor for unmanned systems
  - Turbulence frequently poses problems for air and maritime systems
- Situational awareness - In the air, UAS need the ability to sense objects and avoid them
- On the water, UUVs have to detect, predict the path of, and avoid other moving boats (some at high speed)
  - Observing maritime “rules of the road.” Undersea environment adds additional complexity for UUVs

Survivability, Maneuverability and Situational Awareness

Unmanned Technology and Mission Impact of RAM

- **Unmanned systems demand higher standard for system reliability**
  - **Unmanned systems fielded quickly without requirement for reliability and maintainability (DoD FY2009–2034 Unmanned Systems Integrated Roadmap, 2009)**
  - **What should our requirement be for reliability & maintainability?**
- **Autonomy →teleoperation →semi-autonomy→full autonomy equates to mission endurance**
  - **More system is capable without operator intervention, longer it can execute on its own**
- **Mission Endurance**
  - **Increases as autonomy is realized**
  - **Today – hours, 25 years from now -- months … or longer**
- **Impact on HSI domains of HFE, Manpower, Personnel, Training, Habitability, Safety, Environment, Occupational Health**

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Air Force Lessons Learned for UAS

- Lack of stable/approved requirements
  - Requirements process for unmanned systems not kept pace with evolving technologies
  - Requirements creep and demands for rapid fielding
- Automation of platforms decreases need for people as crew
  - BUT…Personnel needed to support and maintain the vehicles increases
- Increased resources (people, equipment, money) for support and sustainment
  - Radical change in ‘tooth to tail’ personnel ratio - added support manpower
    - Need for experienced middle / senior combatant leaders and decision makers

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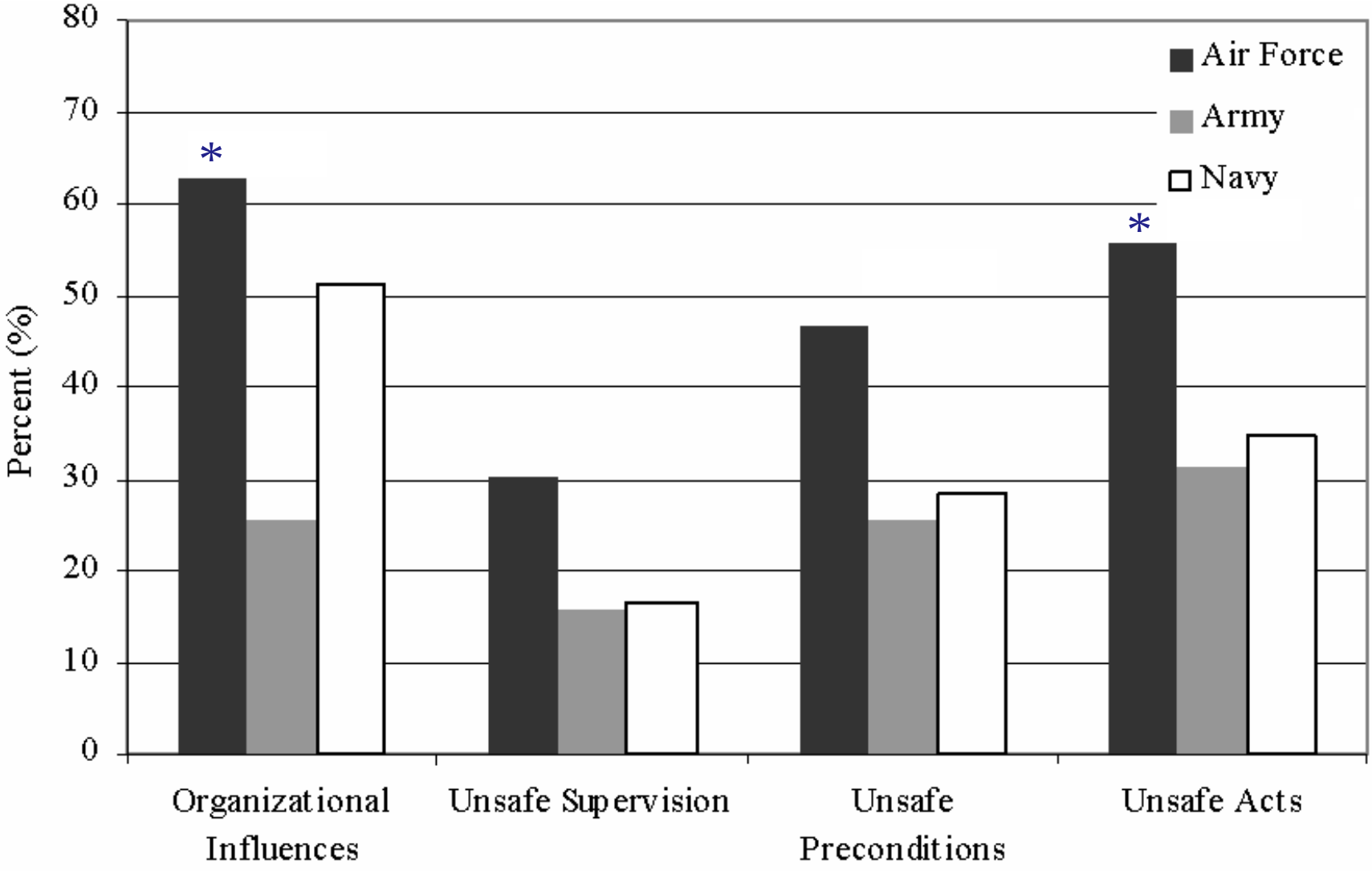
2009 Predator Mishap Statistics – Positive Trends

System	Mishaps / 100,000 flight hours
Predator, MQ-1 (2003)	30
Predator, MQ-1 (2009)	7.5
Reaper, MQ-9 (2009)	15.34
F-22	4.76
F-15/F-16	1.39/1.17
F-4 (1990s)	5.1

OSD UAV Reliability Study, 2003



*statistically significant (P < 0.05)

Class A/B/C Mishaps, 1994-2003

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HFACS Nanocodes and HSI Domain Translation

HSI domains	Human Factors Analysis and Classification System		
	Top level	Root category	Nanocode
Personnel	Organizational	Resource/acquisition management	Accession/selection policies
	Supervision	Planned inappropriate operations	Limited recent experience Limited total experience
	Preconditions	Psycho-behavioral factors	Pre-existing personality disorder Pre-existing psychological disorder
		Physical/mental limitations	Learning ability/rate Motor skill/coordination or timing deficiency
Training	Organizational	Organizational process	Organizational training issues/programs
	Supervision	Inadequate supervision	Local training issues/programs
		Planned inappropriate operations	Crew/flight makeup/composition Proficiency
Manpower	Organizational	Resource/acquisition management	Personnel resources
		Organizational process	Ops tempo/workload
Safety and occupational health	Organizational	Organizational process	Risk assessment - strategic
	Supervision	Failed to correct known problem	Personnel management Operations management
	Preconditions	Adverse physiological states	Pre-existing physical illness/injury/deficit
Personnel survivability	Preconditions	Adverse physiological states	Fatigue – acute Fatigue - chronic

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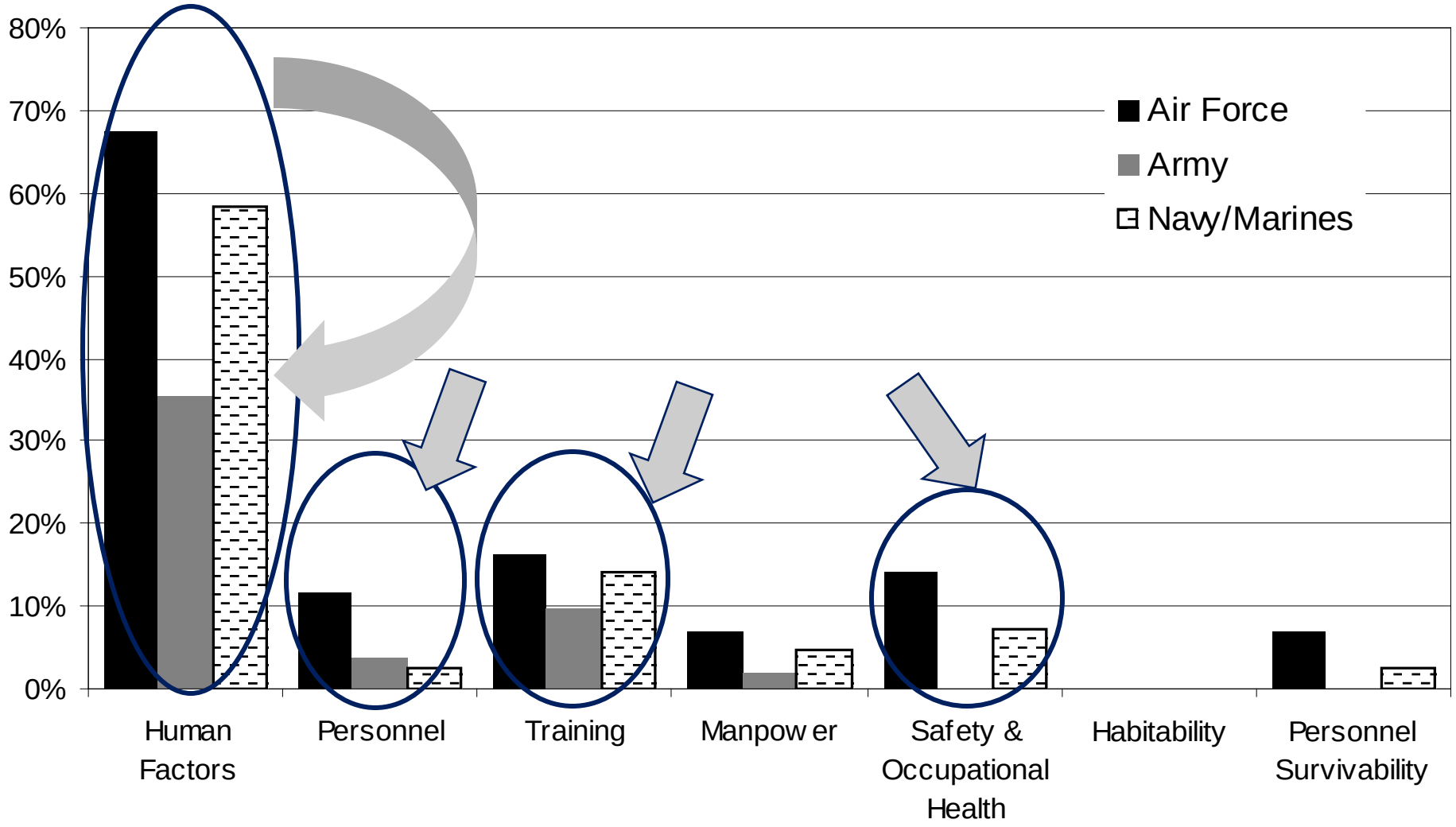
HSI Domains Identified for Highest Payoff



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HSI Domain Comparison

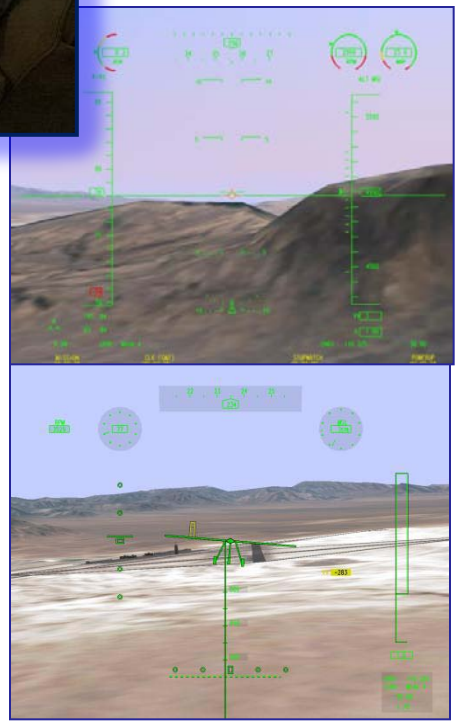
Domain	Air Force	Navy
Manpower	15,000 Airmen (Pilots, SO, Maintainers)	Reduced manpower possibility over manned systems?
Personnel	New career field for USAF RPA operators and for Sensor Operators	"What the unmanned system is doing at that time will determine who operates it…If a vehicle is moving in controlled waters, you want a surface warfare officer. But if we're in an open ocean environment or in a littoral area where there is no aircraft, do you need a rated officer? Probably not."*
Training	Beta test, T-6 training increase, increased system & mission complexity	Likely to increase if new career fields and more systems procured
Human Factors Engineering	Ground Control Station, H-M interface, data fusion	Lessons learned needed for human/machine interfaces; Control Station interface, data fusion and analysis
Survivability	In-theater fratricide	Tethered systems and vulnerability
Environment	Aerial, remote	The Navy requires systems that can be self-sustaining for up to a fortnight while underwater*
Safety	Mishap data, HFACS codes of accidents	Mishap data, HFACS codes of accidents
Occ Health	Unknown at this time ?	Unknown at this time ?
Habitability	Fatigue, shift length, motivation	Launch and recovery, loiter time, shift length

*Admiral Roughead, CNO, Navy League's Sea-Air-Space Exposition, 3 May 2010

Research Lessons Learned

ROVATTS Simulator

- Rapidly reconfigurable research platform; PC-based simulation capability, including sea-based systems
- Explore symbology for Predator operators
  - Exocentric HUD symbology
  - Situation awareness (nose wheel-first landings)
- Individual/team training
- Physiological, psychological and environmental stressors



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Air Force Research Questions

(can the Navy benefit from this research?)

- **What are existing training needs, gaps, and opportunities?**
- **What are Unmanned Systems recruit pool similarities & differences; what is impact on training and mission success?**
- **What alternative training strategies and methods could be used to enhance training, rehearsal, and interoperability?**
- **What subjective and objective metrics could be used to assess and track training and operational success?**
- **What is the cost/fidelity/training effectiveness tradespace for UAS operations?**
- **What alternative approaches and templates for mission planning, performance assessment, and After Action Review (AAR)?**
- **What remediation alternatives exist to improve the quality of UAS candidates before and during initial skills training?**
- **How can the use of game-based and simulator-based scenarios/syllabi impact skill development & performance?**

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Future of Unmanned Systems – Next 25 Years

	2009 Evolutionary Adaptation	2015 Revolutionary Adaptation	2034
Commands	Physical Human Machine Interfaces	Scripted Voice Command/Hand Signals	Natural Language Understanding
Collaboration	Individual System	Teaming w/in Domain Collaboration Across Domains	Teamed Collaboration
Frequency	Constrained RF	Frequency Hopping	Multi-Frequency Communications
Mission Complexity	Operator Controlled		Autonomous Adaptive Tactical Behaviors
Environmental Capability	Limited Environmental Difficulty	Expanded Environmental Difficulty	All-Weather Environmental Difficulty
Product Line	Mission Package Product Line Dependent		Product Line Independent
OPSEC	Signature High		Signature Low
Operational Control	1 Operator / Platform	1 Operator / Domain	1 Operator / Team
Bandwidth	Limited	Advanced Bandwidth Management	Autonomous Bandwidth
Mission Endurance	Hours	Days Months	Years
Maintenance	Operator		Automated
Awareness	Sensor Data	Situational Awareness	Actionable Information

DoD - FY2009–2034 Unmanned Systems Integrated Roadmap, April 2009

Points to Ponder

- Control station human factors/human-vehicle interface issues
  - HSI targets of opportunity are pervasive – with huge potential
    - Person-machine interface
    - Area Of Interest awareness
    - Battlespace Awareness, sensor data fusion and visualization
    - Common, open architecture control stations
- Current design of GCS optimal for controlling multiple aircraft
  - Anecdotal data says maximum of 2 could be successful
  - Lack of comfort with control station interface and capacity to handle Multiple Aircraft Control
  - Poor vehicle control and visualization problems severely handicaps swarm operations

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Points to Ponder

- Teamwork, collaboration, and coordination at a distance
  - Distributed crew concept – using intercom to talk between pilot and sensor operator as opposed to side-by-side operation
- How to coordinate teamwork and team activity via telepresence
  - "Chat room" and "instant messaging" prevalence and familiarity
  - What's next?
- Planning and after action review
  - Desire is to develop capability to …
    - Plan, brief, fly and debrief, collaboratively and at a distance

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Wrap Up and Review

- **Unmanned systems opportunities and challenges for Navy and Air Force**
  - **Human costs are common across Services**
  - **HSI considerations and impacts on all domains**
  - **Research collaboration and sharing lessons learned**

U.S. Air Force
AIM Points

Air Force, Navy officials partner on unmanned aircraft systems

Posted 7/1/2010

"In a signed memorandum of agreement, Air Force and Navy officials partnered to maximize commonality, eliminate redundant effort and increase interoperability between the Broad Area Maritime Surveillance unmanned aircraft systems and the RQ-4 Global Hawk system."

Questions??