Unmanned Platforms: Implications of Mission Autonomy for U.S. Forces

Marshall Hall, Room 155
Fort Lesley J. McNair, Washington, DC
May 19, 2011

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Implications of Mission Autonomy for U.S. Forces

A Transforming National Security Series Event
Marshall Hall, Room 155, Fort Lesley J. McNair, Washington, DC
May 19, 2011

Thursday, May 19th

0745-0800 Welcome

- **Dr. James M. Keagle,** Director, Transforming National Security Seminar Series, Center for Technology and National Security Policy, NDU

0800-0900 Acquisition, Force Structure and Efficiencies

Themes: OSD direction in Better Buying Power in Acquisition Efficiencies. Sustaining growth in autonomy through reuse and refined acquisition approaches.How will unmanned platforms affect force structure? Achieving sustainment growth in Unmanned Systems during a challenging fiscal environment. What role will international partners and private business play in the production of more expendable, unmanned equipment? Are there dual-use and proliferation issues associated with these new capabilities?

- **Mr. Terry Bollinger,** MITRE Technology Analyst for the Office of Naval Research, Code 30 (Expeditionary Maneuver Warfare & Combating Terrorism)
- **Mr. Rich Ernst,** Interoperability Technical Competency Lead, OUSD (AT&L) PSA, Unmanned Warfare
- **CAPT Karl Thomas,** OUSD AT&L PSA (Unmanned Warfare/UAS Task Force)

0900-0915 Break

0915-1015 Lethal Robots: The Ethical Limits of Autonomous Control

Themes: This panel will explore how autonomous systems fail under complex conditions (enemy adaptation, environmental hazards, degradation, malfunctions, etc). What measures can policy-makers take to ensure autonomous and semi-autonomous equipment is thoroughly tested? What standardized safeguards, operational restraints, and rules of engagement should be considered for differing degrees of unit autonomy (Command and Control)? How can policy-makers prepare for the commercial proliferation of semi/autonomous technologies?

- **Professor Ronald C. Arkin,** Director of the Mobile Robot Laboratory, College of Computing, Georgia Institute of Technology
- **Dr. Peter Asaro,** Assistant Professor, New School University; Co-Founder, International Committee for Robot Arms Control
- **Dr. John K. Hawley**, Engineering Psychologist, Human Research and Engineering Directorate Ft. Bliss Field Element, US Army Research Laboratory

1015-1100 Emerging Capabilities for Future Threats

Themes: How big a role will semi/autonomous capabilities play in the future force? What unmanned concepts are emerging to counter future threats? How are the services coordinating their development efforts around unmanned platforms? Are there potential 'game-changers?'

- **Major General R. Mark Brown**, Deputy Assistant Secretary for Acquisition and Systems Management, Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(ALT))

1100-1115 Break

1115-1215 New Strategies for Expendable Systems

Themes: This panel will emphasize doctrine, tactics, techniques, and procedures (DTTP). Discussion of swarms and aggregation, persistent area and unit surveillance; reconnaissance; refueling, repair, and supply; and placing sacrificial platforms in 'harm's way.' Where do unmanned platforms fit in to the high/low mix of U.S. capabilities? How will unmanned platforms affect force structure?

- **Mr. Paul Scharre,** Office of the Secretary of Defense (Policy)
- **Mr. James McCormick,** Program Manager, Tactical Technology Office, DARPA
- **Dr. Adrian Stoica,** Manager, Advanced Robotic Controls Group, NASA-JPL

1215-1315 Lunch

1315-1400 Force Modernization Issues

Themes: Are there specific manpower, equipment, and training issues connected with the proliferation of unmanned, semi-autonomous platforms? How will the separate services handle these potential problems differently? How will the integration of more disposable equipment and frequent, modular upgrades/improvements affect training and deployment cycles?

- **Mr. Grant Begley,** Senior Adviser to the Office of the Under Secretary of Defense - Unmanned Systems (2009-2010)
- **Dr. Jason Stack,** Program Officer, Office of Naval Research (ONR)

1400-1415 Break

1415 -1500 Strategic Assessment

Themes: What capabilities do policy-makers currently expect from unmanned units, and what should they expect over the medium term? What "grand challenges" are likely to drive innovation? How long will the U.S. asymmetric advantage in unmanned technologies hold and where do we stand today? Will ethical concerns about discrimination on the battlefield became a 'game changer' for semi/autonomous equipment? How are such considerations already affecting how the U.S. conducts operations?

- **Mr. Mark Gorenflo,** Principal Deputy to the Deputy Under Secretary of the Navy (Plans, Policy, Oversight & Integration)
- **Rear Admiral Matthew Klunder,** Director of Intelligence, Surveillance and Reconnaissance Capabilities Division, OPNAV N2/N6F2

1500 -1530 The Proliferation of Open Source UAVs

- **Mr. Christopher Anderson,** Editor, Wired Magazine; Founding member of "DIY Drones" online community

1530-1630 Future Wars

What is the likelihood of an 'arms race' in unmanned technologies, and how would this contest be dissimilar to those in the past? How are high and low-tech adversaries likely to adapt to the presence of autonomous systems on the battlefield? How will autonomous behavior be used to improve cross-domain resilience? What processes will help the DoD and private industry prepare for the production of cheaper/faster/stealthier/smaller/expendable units?

- **Lt Col M. Shane Riza,** USAF, ICAF Student and Research Fellow, National Defense University
- **Mr. Albert A. Sciarretta,** Senior Research Fellow, Center for Technology and National Security Policy
- **Mr. Marc Steinberg,** Research Program Officer, Intelligent Autonomy, Office of Naval Research

1630-1700 The Future of Unmanned Systems

- **Major General James O. Poss,** Assistant Deputy Chief of Staff for Intelligence, Surveillance and Reconnaissance Headquarters U.S. Air Force

SPEAKER BIOGRAPHIES

Mr. Chris Anderson

Chris Anderson is currently the editor-in-chief of Wired magazine. Before joining that publication, he worked at The Economist for seven years in various positions and served as an editor at two premier science journals, Science and Nature. Mr. Anderson's publications include The Long Tail, which first appeared in Wired in October 2004 and then became a book, published by Hyperion on July 11, 2006. He is the founder and chairman of BookTour.com and DIYDrones/3D Robotics. He has a background in physics and has conducted research at Los Alamos National Laboratory. He currently lives in Berkeley, California, with his wife and five children.

Dr. Ronald Arkin

Ronald C. Arkin received the B.S. Degree from the University of Michigan, the M.S. Degree from Stevens Institute of Technology, and a Ph.D. in Computer Science from the University of Massachusetts, Amherst in 1987. He then assumed the position of Assistant Professor in the College of Computing at the Georgia Institute of Technology where he now holds the rank of Regents' Professor and is the Director of the Mobile Robot Laboratory. He also serves as the Associate Dean for Research in the College of Computing at Georgia Tech since October 2008. Dr. Arkin's research interests include behavior‐based reactive control and action‐oriented perception for mobile robots and unmanned aerial vehicles, hybrid deliberative/reactive software architectures, robot survivability, multiagent robotic systems, biorobotics, human-robot interaction, robot ethics, and learning in autonomous systems. He has over 170 technical publications in these areas. Prof. Arkin has written a textbook entitled Behavior Based Robotics published by MIT Press in May 1998, co‐edited a book entitled Robot Colonies published in 1997, and a new book to appear in Spring 2009 entitled Governing Lethal Behavior in Autonomous Robots published by Chapman‐Hall (Taylor & Francis). Funding sources have included the National Science Foundation, DARPA, U.S. Army, Savannah River Technology Center, Honda R&D, C.S. Draper Laboratory, SAIC, NAVAIR, and the Office of Naval Research. Dr. Arkin served as the founding co‐chair of the IEEE RAS Technical Committee on Robot Ethics, is on the Board of Governors of the IEEE Society on Social Implications of Technology, and also served on the National Science Foundation's Robotics Council from 2001‐2002. In 2001, he received the Outstanding Senior Faculty Research Award from the College of Computing at Georgia Tech. He was elected a Fellow of the IEEE in 2003, and is a member of the ACM.

Dr. Peter Asaro

Peter Asaro is a philosopher, member of the Faculty of the Department of Media Studies and Film at the New School University, New York and does research and development for Wolfram Research. He has worked in human-computer interface design, artificial intelligence and robotics at the National Center for Supercomputer Applications, the

Beckman Institute, and Iguana Robotics. He has written on cybernetics, new technologies and their ethical and legal challenges, as well as on military robots and just war theory.

Mr. Grant Begley

Mr. Begley is responsible for the corporate business development organization and processes to include opportunity management coupled with cross-corporation strategy, campaign shaping, partnering and implementing cross-business and cross-business unit solutions. Prior to his current position, Mr. Begley served as Pentagon Senior Adviser to the Office of the Secretary of Defense for Unmanned Aircraft Systems. Mr. Begley advised on critical issues leading to the development of policy, enhanced operations, enabled interdependencies and streamlined acquisition for domestic and international unmanned aircraft systems. Mr. Begley's career included assignments to positions of significant leadership in the areas of next generation capabilities at Raytheon, Lockheed Martin and with the U.S. Government. Mr. Begley previously served as Raytheon's Director for Mission Systems and System-of-Systems Integration. He also served as Lockheed Martin's Director for Advanced Capabilities where he initiated successful business thrusts transforming concepts and technologies into robust future-generation weapon system capabilities. Mr. Begley served in the United States Navy for 26 years to include operational assignments flying fighter aircraft, designated Top Gun, followed by acquisition assignments for the development and management of next generation manned and unmanned aircraft systems, weapon systems and joint executive acquisition assignments. Mr. Begley's last government assignment was as the first competitively selected National Director for Counter Stealth and Navy Director for Stealth–Technologies, Policy and Advance Programs. Mr. Begley holds master's degrees in Aerospace and Aeronautic Engineering from the Naval Post-Graduate School and a bachelor's degree in General Engineering from the U.S. Naval Academy. Mr. Begley is Professional Certified by the Department of Defense Acquisition Community in Executive Program Management, Program Management, Classified Program Management, Systems Planning for Research and Development; University of Virginia, Darden Business School - Executive Program Management certified and Massachusetts Institute of Technology – Executive Technical Management certified.

Mr. Terry Bollinger

Mr Bollinger is a subject matter expert for autonomy and cognition at ONR Code 30. He wrote his first paper on the concept of collective intelligence in 1977, ten years before this concept of human-like intelligence in the form of networked components became a topic of psychology. At the NASA Goddard Space Flight Center he built a very early expert system to assess whether this then-new technology could be help Space Shuttle missions shed excess power loads in flight. His most recent paper for AAAI looked at whether embedding

Richard Feynman's Nobel-prize-winning Quantum Electrodynamics theory within classical time flows could suggest new ways to interpret image data faster and more efficiently. He is also the author of a 2003 DoD survey that documented and analyzed use of open source software in the U.S. DoD, and is an internationally invited speaker on open source topics. His survey played a major role in the emergence of the current DoD policy of treating open source software as fundamentally the same as other private sector software. Before moving to ONR he was Chief Scientist for OSD's Defense Venture Catalyst Initiative (DeVenCI), an initiative that was created by SECDEF shortly after 9/11 to help the DoD find and make use of relevant emerging private sector technologies faster and more efficiently. Through DeVenCI he helped the Venture Capital community understand and make better use of DoD opportunities for small companies. Mr Bollinger was an editor for IEEE Software for six years, an Assistant Editor-in-Chief for two of those years, and edited two focus issues for Software. He has Master's and Bachelor's degrees in Computer Science from Missouri S&T, and received a Professional Degree from MS&T in late 2009.

MG Robert Brown

MG R. Mark Brown is the Deputy for Acquisition and Systems Management for the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(ALT)). MG Brown is responsible for executive program management oversight for cost, schedule, and technical performance as well as implementation of acquisition policy and systems integration for over 600 Army aviation, missile, ground combat, intelligence/electronic warfare, communications, ammunition, chemical/biological defense, combat/service support, Soldier, business enterprise, modeling & simulation, and other special access programs with an annual budget of over $55 billion. He is the direct link between the Army Acquisition Executive (AAE) and the Army's 12 Program Executive Offices (PEO) by providing guidance, assistance, and direction. He also functions as the Army Acquisition Operations Chief for oversight of equipment in overseas operations to include Operation Iraqi Freedom and Operation Enduring Freedom. MG Brown is a graduate of the United States Military Academy, where he received his commission as an Armor officer. He received an MS in Systems Engineering from Virginia Tech. He is also a graduate of the U.S. Army Senior Service College Science and Technology Fellowship at the University of Texas-Austin; the U.S. Army Command and General Staff College; the Executive Program Manager's Course; the Advanced Program Management Course of the Defense Systems Management College; and the Training with Industry Program at BMY Defense Group in York, Pennsylvania (now BAE). MG Brown served in a wide variety of command and staff positions during his career. Prior to his current assignment, he served as the PEO Soldier and the Commanding General for the Army Materiel Command's (AMC) Natick Soldier Systems Center; the Deputy Commanding General, U.S. Army Research, Development and Engineering Command; Chief of Staff and Senior Military Assistant to the Honorable

Claude M. Bolton, Jr., the ASA(ALT) and AAE; Commander of Defense Contract Management Area Baltimore; Special Assistant to the Deputy Assistant Secretary of the Army (Procurement), Office of the ASA(ALT); Commander of Defense Contract Management Command Clearwater, Florida; Military Assistant to the Secretary of the Army; Procurement Program Analyst, Office of the Chief of Staff, Army; Chief of Army Acquisition Corps Personnel Policy, Office of the Deputy Chief of Staff for Personnel; Procurement and Nuclear Weapons Assignments Officer, Total Army Personnel Command; and Armored Systems Modernization Program Procurement Officer and later Armored Systems Modernization Milestone Decision Project Leader at AMC. As a company grade officer, MG Brown commanded two companies and served in key leadership positions in the 1st Infantry Division, the 2nd Armored Division, and Joint Task Force Bravo in the Republic of Honduras. His military decorations include the Defense Superior Service Medal, Legion of Merit (with oak leaf cluster), Defense Meritorious Service Medal, Meritorious Service Medal (with five oak leaf clusters), Joint Service Commendation Medal, Army Commendation Medal (with oak leaf cluster), Army Achievement Medal, Joint Meritorious Unit Award (with oak leaf cluster), and the Army Staff Identification Badge. He is married to COL (Retired) Mary K. Brown, U.S. Army.

Mr. Rich Ernst

Mr. Rich Ernst is the lead for OUSD AT&L for UAS Common Development and Interoperability across DoD Services. With OSD leadership, he has kicked-off the Unmanned Control Segment Open Architecture (UCS OA) to address the emerging need to obtain interoperability across unmanned air assets. Application of the UCS OA will allow programs to improve awareness and control Total Ownership Costs (TOC), increase interoperability, improve Warfighter capabilities and reduce integration timelines. Mr. Ernst's efforts on open approaches are based on open standards; services based architectures, open source collaboration, and reference open source implementations. The shift to an open architecture approach will enable a business process migration from proprietary products that can only be changed by one vendor, towards a marketplace for professional services to extend and adapt capabilities on demand. These approaches, coupled with formal tools will allow the Department of Defense to benefit from:

- Reduction in Total Ownership Cost (TOC)
- Modularity / minimization of complexity
- Reduction in financial risk and lock-ins
- Reduction in the cost of unmanned system R&D and T&E
- A decrease in the overall time to roll out new technologies to the warfighter

Mr. Mark Gorenflo

Mark Gorenflo is the Principal Deputy for the Deputy Under Secretary of the Navy for

Plans, Policy, Oversight & Integration [DUSN (PPOI)]. The DUSN (PPOI) serves as the Secretary of the Navy's primary advisor on foreign and defense policy, intelligence and naval capabilities and readiness. He was appointed to this position in July 2009. Mr. Gorenflo was first appointed to the Senior Executive Service as the Deputy Assistant Secretary for Policy for the Department of Veterans Affairs in April 2008. From September 2007 to April 2008, he served as Acting Principal Director, Forces Transformation & Resources for the Assistant Secretary of Defense for Special Operations/Low Intensity Conflict & Interdependent Capabilities. From August 2005 to August 2007, Mr. Gorenflo worked for the Vice Chairman of the Joint Chiefs of Staff, ADM E. P. Giambastiani, USN. His first appointment in the Civil Service was as the Director of the Commander's Advisory Group for the Supreme Allied Commander Transformation/Commander U.S. Joint Forces Command in Norfolk, Virginia from October 2004 to August 2005. From 1983 to 2004, Mr. Gorenflo served as a submariner in the United States Navy, retiring as a Commander. During his Navy career, he served aboard USS Norfolk (SSN 714), USS Montpelier (SSN 765) as new construction Engineer, USS Georgia (SSBN 729)(Blue) as Executive Officer and commanded USS Parche (SSN 683). Mr. Gorenflo graduated with distinction from the United States Naval Academy in 1983. He went on to receive a master of arts degree in politics and philosophy as a Rhodes Scholar from the University of Oxford in 1985. He is a Life Member of both the U.S. Naval Institute and the Naval Submarine League.

Dr. John Hawley

Dr. John K. Hawley currently is a senior technical staff member at the US Army Research Laboratory’s Human Research and Engineering Field Element at Ft. Bliss, Texas. He received his PhD in psychology from the University of North Carolina at Chapel Hill in 1977. Since receiving his doctorate, Dr. Hawley has worked as an applied psychologist for more than 30 years in a variety of government and private-sector organizations. These include the US Army Research Institute for the Behavioral and Social Sciences and the US Army Research Laboratory. Dr. Hawley began working with Patriot and other automated air and missile defense systems in the late 1970s, and has extensive technical and operational experience with them. He has written more than 100 journal articles, technical reports, trade journal articles, and book chapters on the subjects of human-system integration and human performance in complex military systems. Dr. Hawley recently served as project lead for an Army effort to examine human performance contributors to fratricides involving the Patriot air and missile defense system during the Second Gulf War (Operational Iraqi Freedom) and recommend potential solutions. He is now working with the air defense community to implement selected recommendations involving system design practices, human-system integration practices, test and evaluation methods, personnel assignment practices, and operator and crew training. Dr. Hawley’s professional experience has been devoted to helping people and organizations manage the human side of transitions to new systems,

processes, and technologies.

Dr. James Keagle

Dr. James M. Keagle is the Director of the Transforming National Security seminar series at the Center for Technology and National Security Policy at the National Defense University. Prior to this position, Dr. Keagle served for nine years as the National Defense University's Provost (effective 2004) and Vice President for Academic Affairs (effective 1999). Prior to these positions, he served as a professor of National Security Strategy at NDU. In that role Dr. Keagle worked as a research faculty member assisting with NDU's modeling and simulation and work with interagency education and training. Accepting an appointment to the U.S. Air Force Academy, he graduated 2nd academically in his class in June 1974. Following graduation, he went to the University of Pittsburgh to complete his Master's of Arts degree in political science and earned a graduate certificate in Latin American studies (1975). After a tour as a munitions maintenance officer, Dr. Keagle went on to become an assistant professor of political science at the U.S. Air Force Academy. In 1980, he went on to Princeton University where he completed both a Master's of Arts degree (1981) and Ph.D. (1982) in politics. He proudly notes his honorary Ph.D from the Military Technical Academy of Romania--the only United States citizen so honored. Following his extensive education, Dr. Keagle's next six tours were political-military assignment that included direct access and interaction with Cabinet-level government officials on national security related matters. These assignments included work for two Combatant Commanders as a senior strategist; for the Office of Secretary of Defense pertaining to Cuba; Deputy Director, Office of the Secretary of Defense Bosnian Task Force; and for the Deputy Under Secretary of the Air Force in International Affairs as Senior Strategist. Military. For the last two years he has led multiple NATO and Defense Education Enhancement Teams to Georgia, Azerbaijan, and Montenegro. Since leaving military service, Dr. Keagle has held the position of adjunct professor at a number of institutions to include: Syracuse University, American University, Central Michigan University, Catholic University, University of Colorado, and Lake Superior State College. He also holds an honorary professorships with Transilvania University in Brasov, Romania, as well as the Mongolian Defense University--again, the only American so honored . Dr. Keagle and wife Kay are the proud parents of three adult children.

RDML Matthew Klunder

Rear Admiral Klunder, a native of Alexandria, Va., graduated from the United States Naval Academy in 1982 and earned his wings of gold at Meridian, Miss., in September 1984. Subsequent flying tours were based in Naval Air Station (NAS) Miramar, Calif.; NAS Patuxent River, Md.; Naval Air Facility Atsugi, Japan; and NAS Lemoore, Calif., where he was qualified in numerous aircraft including the E-2C Hawkeye and F/A-18 E/F Super

Hornet. Klunder has served at sea in Airborne Early Warning Squadron (VAW) 112, VAW-115 as a department head, VAW-115 as commanding officer, and Carrier Air Wing 2 as air wing commander. He has made eight deployments and multiple surge operations to the Atlantic, Pacific, and Indian Oceans and to the Mediterranean Sea and Arabian Gulf. Klunder's shore tours include serving as a flight instructor, Naval Air Training and Operating Procedures Standardization officer and Commander Naval Air Force, U.S. Pacific Fleet evaluator at VAW-110; test pilot/project officer at Force Warfare Test Directorate; senior operations officer and Single Integrated Operational Plan officer at the Joint Staff J-3/National Military Command Center; as Joint Staff liaison officer and section chief at the U.S. State Department; as Combined Air Operations Center deputy director at Al Udeid Air Base in Qatar; and deputy director for Information, Plans, and Security for OPNAV N3/N5. Highlights during these tours include receiving the 1988 Hawkeye of the Year award, the 1991 Test Pilot of the Year award, and the 2002 George C. Marshall Statesman award. In July 2010, Klunder reported as director of Intelligence, Surveillance and Reconnaissance Capabilities Division, OPNAV N2/N6F2 following his assignment as the 83rd commandant of midshipmen at the U.S. Naval Academy. Klunder received his Bachelors degree from the U.S. Naval Academy and his Master's degrees in Aerodynamics and Aviation Systems from the University of Tennessee and Strategic Studies from the National War College. He has flown over 45 different aircraft and accumulated 21 world flying records. His awards include the Legion of Merit (3 Awards), Defense Meritorious Service Medal (2 Awards), Meritorious Service Medal (2 Awards), Joint Commendation Medal (2 Awards), Navy Commendation Medal (4 Awards), and various unit and campaign awards.

Mr. James McCormick

Mr. Jim McCormick joined DARPA in August 2004 and specializes in the development, acquisition, and oversight of unmanned aerial vehicle systems. He is currently focused on advanced control concepts and distributed net-centric enablers. In five years as a DARPA Program Manager, McCormick has established a record for identifying and advancing high-risk, high-payoff technologies, directing the first ever air-to-air refueling of a fully autonomous aircraft. In 24 years in the United States Air Force, McCormick served in a variety of fields including acquisitions, aircraft maintenance, and intelligence. He managed several programs at the Air Force Research Laboratory at Wright-Patterson Air Force Base and was instrumental in establishing the Pentagon's Office of the Under Secretary for Intelligence. McCormick holds a Bachelor of Science degree in mechanical engineering from Rensselaer Polytechnic University and Masters of Business Administration from Utah State University.

Major General James Poss

Maj. Gen. James O. Poss is the Assistant Deputy Chief of Staff for Intelligence, Surveillance

and Reconnaissance, Headquarters U.S. Air Force, Washington, D.C. He is responsible to the Secretary and Chief of Staff of the Air Force for policy formulation, planning, evaluation, oversight, and leadership of Air Force ISR capabilities. General Poss received his commission through the Reserve Officer Training Corps program at the University of Southern Mississippi. He served in Desert Storm with the U.S. VII Corps RC-12 Guardrail Battalion in Saudi Arabia, and was Director of Intelligence for Central Command Air Forces deployed to Southwest Asia at the beginning of Operation Enduring Freedom. The general commanded the 488th Intelligence Squadron, Royal Air Force Mildenhall, England, flying RC-135s in combat during the Kosovo Air War. He has also commanded the 609th Air Intelligence Group at Shaw AFB, S.C., and 70th Intelligence Wing at Fort George G. Meade, Md. The general has previously served as the Director of intelligence at both Headquarters U.S. Air Forces in Europe and Air Combat Command. Prior to his current assignment, he was Director, ISR Strategy, Integration and Doctrine, Deputy Chief of Staff for Intelligence, Surveillance, and Reconnaissance, Headquarters U.S. Air Force.

Lt Col Shane Riza

Lieutenant Colonel Riza is a member of the class of 2011 and the Robotics and Autonomous Systems Industry Study team at the Industrial College of the Armed Forces, Ft. McNair, D.C. He is a command pilot with 2900 total hours, 2600 hours in the F-16, and is a graduate and former instructor of the United States Air Force Weapons School, Nellis Air Force Base, Nevada. Colonel Riza is a veteran of Operations Southern and Northern Watch and commanded the 14th Fighter Squadron during Operation Iraqi Freedom. He entered the Air Force in 1990 upon graduation from the United States Air Force Academy where he earned a Bachelor of Science in Aeronautical Engineering. He is a graduate of Air Command and Staff College, Maxwell Air Force Base, Alabama and served on staff at Headquarters United States Air Forces in Europe. His thesis from Air Command and Staff College, “The Operational and Tactical Nexus: Small Steps Toward Seamless Effects-Based Operations,” was published by Air University Press as a Wright Flyer paper, and he published “A Grand Unified Theory of Fighter Quantum Mechanics: The Case for Air-to-Air Training in Multi-Role Fighters” in the Weapons School’s official magazine, The Weapons Review. As a Research Fellow at the Industrial College of the Armed Forces, he recently completed a book titled Killing Without Heart: Limits on Robotic Warfare in an Age of Persistent Conflict for which he is currently seeking publication. Upon graduation Colonel Riza will command the 354th Operations Group at Eielson Air Force Base, Alaska.

Mr. Paul Scharre

Paul Scharre works in the Office of the Under Secretary of Defense for Policy where he oversees policies on unmanned systems and intelligence, surveillance, and reconnaissance (ISR) programs. Prior to joining OSD, Mr. Scharre served six years in the U.S. Army where

he led a reconnaissance team in the 3rd Ranger Battalion as part of the joint counter-terrorism task force in Afghanistan. He completed four tours to Iraq and Afghanistan between 2002 and 2008. Mr. Scharre has published and presented in multiple forums on policy and technical topics, including publications in Armed Forces Journal, Physical Review D, and presentations at the National Conference of the American Physical Society and defense-related conferences. His article "Why Unmanned?" appeared in the most recent (April) issue of Joint Force Quarterly. Mr. Scharre's essay on autonomy was a 2009 US Naval Institute Robotics Essay Contest winner. Mr. Scharre holds an M.A. in Political Economy and Public Policy and a B.S. in Physics, both from Washington University in St. Louis.

Mr. Albert Sciarretta

Mr. Albert A. Sciarretta is a Senior Research Fellow at the Center for Technology and National Security Policy (CTNSP), National Defense University. As a Senior Research Fellow, he assesses Army S&T efforts; as well as broader DoD irregular warfare (IW) topics; including human, social, cultural behavior modeling and IW-focused analytical tools, methodologies, metrics, and data. He recently led an assessment of Army micro-autonomous systems and results were published in CTNSP Defense & Technology Paper #80. He also participated in a CTNSP effort to assist NATO in developing a methodology and metrics for transitioning Afghanistan provinces to the central government of Afghanistan. Mr. Sciarretta is also president of CNS Technologies, Inc. He supports DoD efforts related to assessing advanced military technologies, developing science and technology (S&T) investment strategies, and designing and executing tactical through operational demonstrations and experiments which include the development of metrics and the use of integrated live-virtual-constructive simulations. He is a subject matter expert on various S&T topic areas, as well as test and evaluation, modeling and simulation, counterterrorism, assessment of human performance, and urban operations. He has designed and conducted experiments involving unmanned systems and is assisting the Defense Test Resource Management Center in identifying capability needs for testing autonomous systems. Mr. Sciarretta is a retired Army armored cavalry officer, whose service included operational assignments, instructing at the U.S. Military Academy, acting as a technology officer on armored vehicle task forces, and serving as Assistant to the Chief Scientist, Army Materiel Command. He has dual M.S. degrees — Operations Research and Mechanical Engineering — from Stanford University, and a B.S. degree in General Engineering from the U.S. Military Academy. He has participated in many study committees at the National Academy of Sciences (NAS) and within the DoD; as well as independent review teams. He is currently a member of an NAS committee on "Making the Soldier Decisive on Future Battlefields."

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SPEAKER BIOGRAPHIES

Dr. Jason Stack

Jason Stack received the Ph.D. degree from the Georgia Institute of Technology in Electrical & Computer Engineering. He currently serves as a Program Officer for the Office of Naval Research in the Ocean Battlespace Sensing department. His portfolio includes basic & applied research in machine learning and autonomy; sensor development for the underwater domain; and advanced development in mine warfare, explosive ordinance disposal, and open architecture command & control. He is the US lead for a NATO Joint Research Project on machine intelligence & autonomy for mine countermeasures and is a cofounder of the Mine Warfare Community of Interest focusing on data standards and systems interoperability. Dr. Stack holds over 40 publications and 2 patents in the fields of signature recognition and autonomous systems.

Mr. Marc Steinberg

Marc Steinberg is a program officer at the Office of Naval Research, where he manages basic and applied research programs in autonomy. At the basic research level, he focuses on highly multi-disciplinary autonomy research that cuts across different technical areas and mission domains. Some of the types of fields that are involved include control theory, computational intelligence, human factors engineering, and related fields such as biology/animal behavior/cognition, economics/game theory, cognitive science/psychology, and neuroscience. At the applied research level, he focuses on autonomous air systems and on multivehicle collaborative systems that may include collaboration between air and other naval systems. Prior to coming to ONR, he was a technical fellow and principle investigator on a wide range of basic and applied research projects that dealt with applications of computational intelligence to aerospace control, autonomous control, survivability, vehicle management systems, prognostics and health management, and robust, adaptive, nonlinear, and reconfigurable control. He has also worked on a number of systems development programs to help transition and mature advanced technologies to operational use. He has authored or co-authored papers on a range of related subjects and received numerous professional society awards for his technical contributions including the Derek George Astridge Award for Contribution to Aerospace Safety (British Institution of Mechanical Engineers), the Dr. George Rappaport Best Paper Award (IEEE National Aerospace Electronics Conference), the 2nd Best Paper of Conference Award for AIAA Guidance, Navigation, and Control Conference, and has twice-won Pathfinder Best Paper awards for AUVSI Unmanned Systems North America. He has received B.S. and M.S degrees in Mechanical Engineering from Lehigh University in 1989 and 1992 respectively and has since received a second M.S. degree in Human Factors Engineering.

Dr. Adrian Stoica

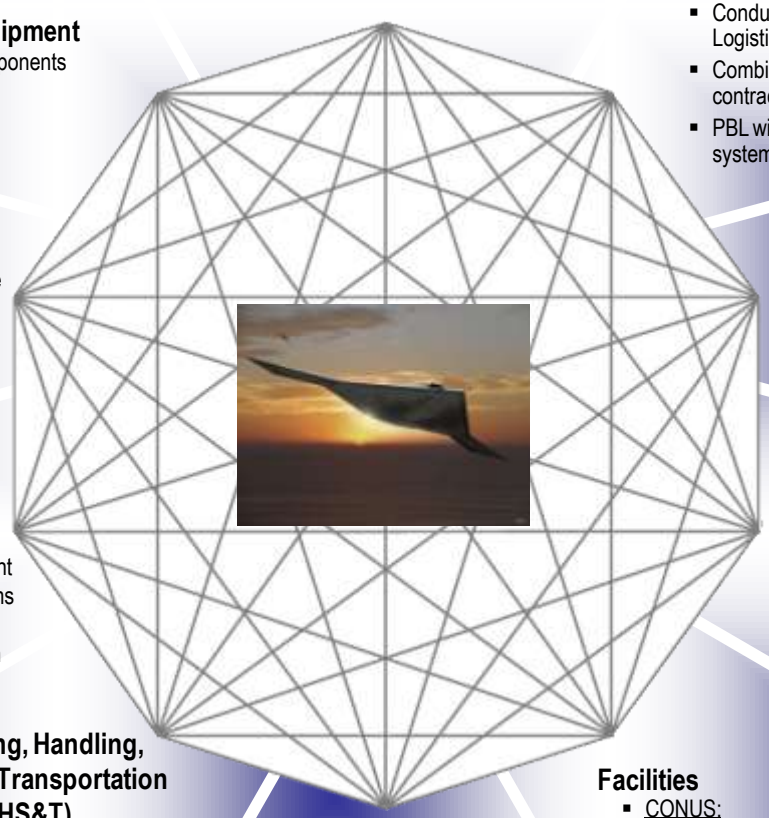
Dr Adrian Stoica is a Senior Research Scientist and Manager of the Advanced Robotic

Control Group in the Autonomous Systems Division, NASA Jet Propulsion Laboratory (JPL). At JPL since 1996, he has been Principal Investigator in many government-funded projects (including 5 projects for DARPA) and has pioneered new technologies in diverse areas, such as adaptive and evolvable hardware for autonomous systems, biometrics, anti-tamper, humanoid robots and brain-machine interfaces. He has been reviewer and expert in a number of advisory boards and panels, for US Government, European Commission, other Governments and Institutions. He founded 4 conferences on topics related to Autonomous Systems and Security, the oldest conference running annually since 1999.

Captain Karl Thomas

CAPT Thomas received his commission through the NROTC program at Rensselaer Polytechnic Institute in 1986 after graduating with a degree in Management Systems, and earned a Master's degree in Information Technology from the Naval Postgraduate School in Monterey, California. He is an E-2C Hawkeye Naval Flight Officer, and commanded VAW-117 aboard USS NIMITZ (CVN 68) in support of Operation Iraqi Freedom. After graduating from Nuclear Power School, CAPT Thomas served as Executive Officer of USS DWIGHT D. EISENHOWER (CVN 69). He was reassigned as Executive Officer of USS GEORGE WASHINGTON (CVN 73) in July 2008, delivering the first permanently forward deployed nuclear aircraft carrier to Japan. In 2009, he commanded the Sixth Fleet Command Ship, USS MOUNT WHITNEY (LCC 17). He currently serves in OUSD AT&L (Unmanned Warfare) and coordinates the OUSD AT&L Unmanned Air Systems Task Force, leads the Interoperability IPT, and is study director for the Unmanned Interoperability Initiative.

Unmanned Systems
Much More Than "The Platform"



Communications

Design & Interface

Supply Support
- Conducting Performance Based Logistics (PBL)
- Combination of organic and contractor supply support
- PBL with commonality between systems

Training and Training Support
- Courseware
- Devices (crew & operator)
- Modeling and Simulation

Computer Resources Support

Facilities
- CONUS:
  - Common maintenance hub
- OCONUS:
  - EUCOM –
  - CENTCOM –
  - PACOM –

Maintenance Planning
- Common I-Level and D-Level opportunities
- Leveraging UAS PHM

Packaging, Handling, Storage & Transportation (PHS&T)
- Commonality across the platforms

Technical Data
- Configuration Management
- Open Architecture Systems Integration
- New Technology Insertion

Manpower and Personnel
- Operators capable of conducting operations with other services
- Ability to perform mutually supportive maintenance based on service specific requirements and basing/maintenance locations

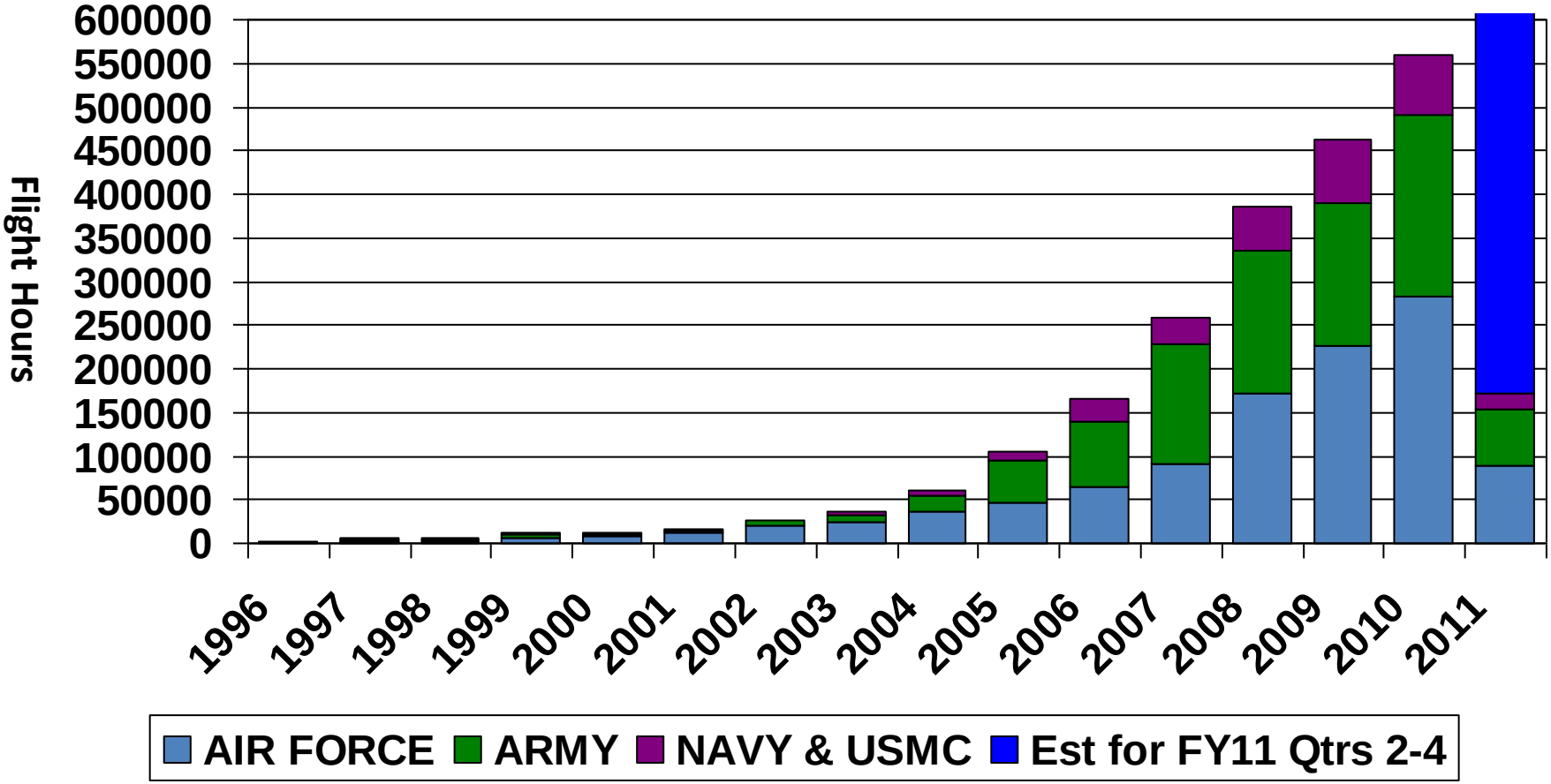
Support Equipment
- Commonality of components & basing locations

Unmanned Systems Success can only be Accomplished at a System Level

DoD UAS Flight Hours

(By Department, By Fiscal Year)

As of December 31, 2010



Number of Fielded UAS and Flight Hours Continued Near-exponential Growth.

Planning the Future of Unmanned Platforms

Terry Bollinger
MITRE Technology Analyst for ONR Code 30

May 19, 2011

Questions

- **Will DoD fully control the technology of its future unmanned platforms?**
  - No. It does not now.
- **Will dual-use be a major factor?**
  - Yes. DoD will still drive innovation, but lag in application.
- **What is the best acquisition strategy?**
  - One that maximizes reuse, minimizes support churn, & maximizes ability to innovate quickly (the I-4 model).
- **How will future unmanned platforms affect force structure?**
  - Radically, **if** very smart systems can be made cheaply.

Estimating Private Sector Interest

- **What really drives heavy private sector investment in a new technology area?**
  - Most critical factor: Opportunity for a very large market
  - Venture Capitalists lose money on niche markets
  - Also vital: the product *must* be persuasively "new"
- **How will autonomy look for investment?**
  - The mass-market sales opportunities for deep autonomy are staggering, *if* such systems can be built (& cheaply)
  - Why: Books automated memory; computers automated following orders; deep autonomy automates *everything*
- **But isn't DoD more platform focused?**
  - Yes, but deep autonomy will easily convey and compete

Does DoD Own Unmanned Platforms?

- **Question: Does DoD really own most of its internal software infrastructure?**
  - A question for DoD computer or network users: *When was your last work day when you did* not *use software from a major private sector vendor?*
  - The Good: DoD does not own it (lower support costs)
  - The Bad: DoD does not own it (unverifiable software)
  - This paradox has no easy solution, and it is expanding
- **Question: Will DoD really own unmanned platform designs and software?**
  - Unmanned systems are *always* software intensive.
  - The same market forces that drove DoD to use so much commercial software will inevitably also drive robotics

But Isn't DoD a Major Research Driver?

- **Absolutely!**
  - George Solhan, Director, ONR Code 30:

    "We can't support small teams of Marines using robotic platforms whose sensors cost hundreds of thousands of dollars, and whose software cost millions or in some case billions of dollars to develop."
- **The new push in autonomy research:**
  - Smaller
  - Cheaper
  - Faster
  - *Smarter*
- **ONR is working this for ground and air**

So Doesn't that Make DoD the Driver?

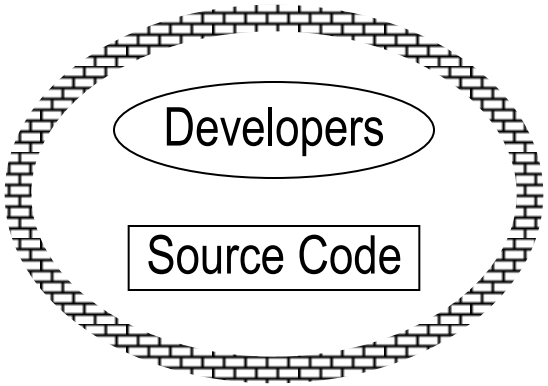
- **Nope.**
  - We *fund* advanced research, but often don't deploy it.
  - Good research often disappears into "stealth mode." (The private sector keeps its secrets better than DoD.)
  - When the research reappears, it is almost always slanted towards some private sector *mass* market.
  - There's no slight intended, just simple economics.
- **OSD Defense Venture Catalyst Initiative**
  - This SECDEF-originated program works to fix this.
  - DoD learns more about early "stealth" companies.
  - Venture Capitalists learn more about DoD needs.
  - For unmanned platforms, private sector results will grow in importance as DoD "seed money" begins to bear fruit.

Ashton Carter's Memo

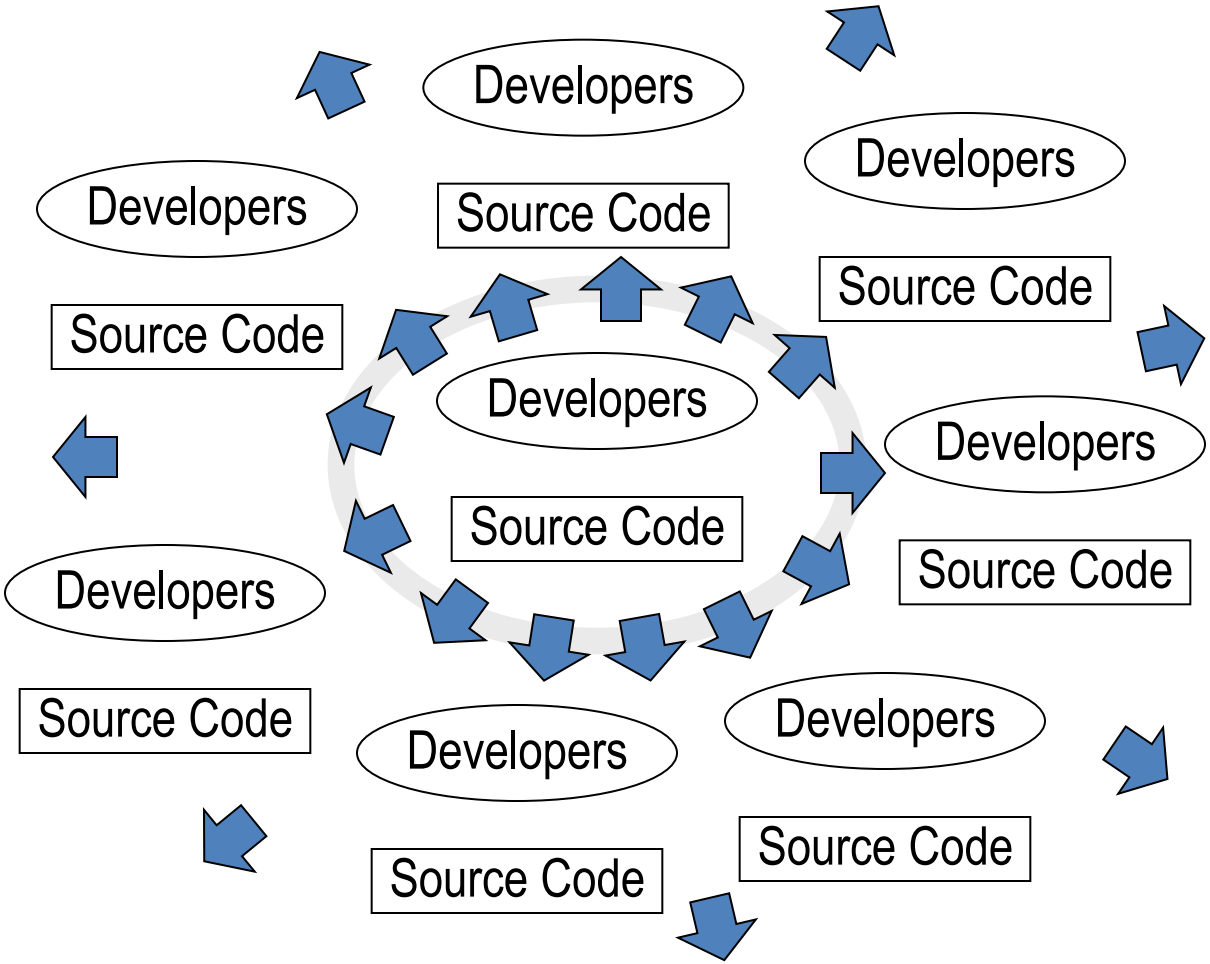
- **Issued 14 Sept 2010. Policy Title:**
  - "Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending"
- **Example recommendations:**
  - Mandate affordability
  - Eliminate development redundancy
  - Remove obstacles to competition
  - Require open architectures
  - Entice small businesses to participate
  - Eliminate "make work" with low-value outcomes
- **How might this be accomplished for emerging unmanned acquisitions?**

A Tale of Two Software Development Models

Proprietary



Cooperative



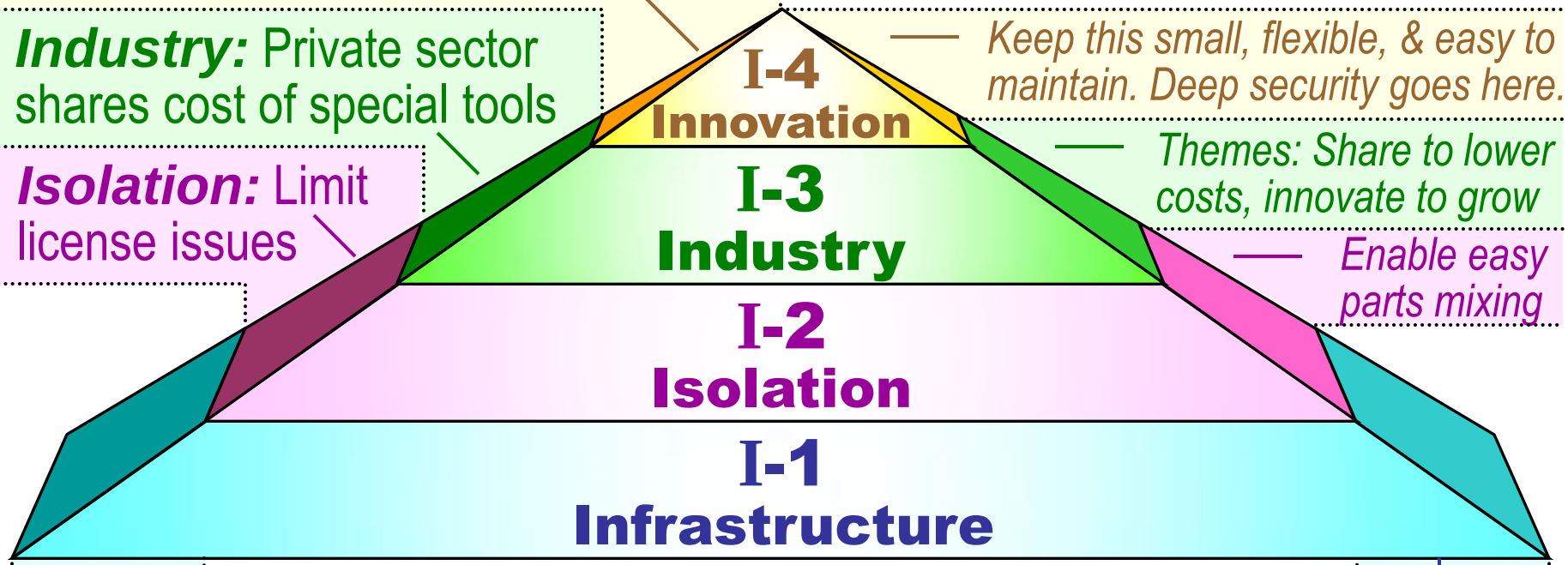
I-4 Pyramid

Maximizing Acquisition Benefits

Innovation: Ideas that combine past work in highly novel new ways

Industry: Private sector shares cost of special tools

Isolation: Limit license issues



Keep this small, flexible, & easy to maintain. Deep security goes here.

Themes: Share to lower costs, innovate to grow

Enable easy parts mixing

Good infrastructure is full of highly mature ("time to move on") solutions

Infrastructure: Components whose benefits increase with wider sharing

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But What Will the Structural Impact Be?

- **If "smart" cannot be done at all…**
  - Impact of unmanned platforms will devolve into an extended variation of buying better hammers.
  - The reason: Such automation simply envelops existing warfighter personnel in more (and more remote) layers of metal. Human limits continue to define the structure.
- **If "smart" is possible only at great cost…**
  - Same result, mostly. Like computers that cost too much.
- **If "smart" can be done *cheaply…***
  - The defense world quickly gets very, very interesting.
  - No assumption can be left unexamined in this scenario.
  - Technical Teaser: *Keep an eye out for methods that share a probabilistic concept of "fast future estimation."*

References

Ashton Carter, “Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending”, 14 Sept 2010. http://www.acq.osd.mil/docs/USD_ATL_Guidance_Memo_September_14_2010_FINAL.PDF

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Author: terry@mitre.org, 703 983-5638

U.S. Army Research, Development and Engineering Command

US ARMY RDECOM

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Practical Limits of Control:
Lessons from the Patriot Vigilance Project

john.k.hawley@us.army.mil

Setting the Stage: Patriot During the Second Gulf War

During the combat operations phase of the Second Gulf War (Operation Iraqi Freedom)—March-April 2003, Army Patriot units were involved in two fratricide incidents involving coalition aircraft:

- British GR-4 Tornado – misclassified as an anti-radiation missile (ARM)
- U.S. Navy F/A-18 – misclassified as a tactical ballistic missile (TBM)

U.S. Patriot units hit everything they shot at, but …
two of the 11 U.S. Patriot shots were fratricides (18%)

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Why is Patriot "Relevant"?

- Existing system—in the Army's inventory since the mid 1980s
- Extensive availability of automation to support air battle management
- Operational concept and operating environment has evolved significantly and become more complex
  - Increasing technical and tactical complexity "flows through" directly to operators
- As Patriot evolved it acquired features and characteristics more typical of systems the rest of the Army will employ than those in the current inventory
  - Network-enabled—and dependent
  - Complex—an early "system of systems" configuration
  - Knowledge-intensive
- There are lessons in the Patriot experience for concepts and technologies now coming of age across DoD

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

How'd We Get Started?

- MG Vane's question via e-mail in March 2004:
  - "How do you establish vigilance at the proper time? 23' 59" of boredom followed by 1" of panic?"
- MG Vane expressed a concern about
  - "Lack of vigilance" on the part of Patriot operators
  - Resulting "lack of situation awareness" (SA)
  - General "lack of cognizance" of what's being presented on situation displays
  - Resulting "unwarranted trust in automation"
- MG Vane was interested in
  - Understanding how we got to the fratricide incidents—human performance contributors
  - Identifying interventions that could be implemented now
- This encounter set us off on a six-year effort, the Patriot Vigilance project

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Recommendations

1. Re-examine automation concepts, operator roles, and command and control relationships in air and missile defense (AMD) battle management systems to emphasize effective human supervisory control (HSC)
   - The solution is not to try to re-insert the operators as traditional manual controllers; engagement situation is too complex and demanding for that option
   - Automation recasts operators as supervisory controllers and brings in everything that goes with that control mode
2. Develop more effective air battle management personnel: "Re-look the level of expertise required to employ such a lethal system on the modern battlefield"

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

What is Effective HSC?

- Soldiers and not the automated system are the ultimate decision makers in AMD firing decisions
- Decisions to shoot or not to shoot made by crews having (1) the technical potential for adequate SA and (2) the expertise to understand the significance of the information available to them (sensemaking ability)
  - The latter requirement is critical to developing situation-specific trust in automation
  - Situation-specific trust is essential to managing automation unreliability—a consequence of the "brittleness problem:" inability to reliably handle unusual or ambiguous situations
  - Training and crew preparation critical here
- Uncritical acquiescence to the automated system's recommendations is not effective human supervisory control (automation bias)

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Independent Support

- "The Patriot system should migrate to more of a 'man-in-the-loop' philosophy versus a fully automated philosophy—providing operator awareness and control of decision processes"
- "Patriot training and simulations should be upgraded to support this man-in-the-loop protocol including the ability to train in confusing and complex scenarios that contain unbriefed surprises"

Source: Report of the Defense Science Board Task Force on Patriot System Performance, November 2004.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Observations Relevant to Future Automated Systems

- Need to change the way decision makers, system developers, and users think about automation and autonomy—topic area is fraught with misconceptions
- The Patriot experience highlights the well-known fact that automation changes operator roles and brings with it the problems associated with supervisory control
  - The brittleness problem of automata and the Catch-22 dilemma (Don Norman's "dangerous middle ground")
  - Simple trust vs. distrust in automation versus need for situation-specific trust
  - Training for automated operations can be more complex and demanding than training for manual control
- Must better apply what is known about automation and supervisory control to actual systems: concept development, design, testing, training, CONOPs, and TTP

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

The Catch-22 of HSC

- Automation has been introduced because it is thought to be able to do the job better than a human operator—"humans are becoming the weakest link in increasingly complex defense systems"
- But…humans have been left in the control loop to "monitor" that the automated system is performing correctly and override the automation when it is "wrong"
- Tacit assumption: Operators can properly decide when the automation's decisions should be overridden
- Humans are expected to compensate for automation unreliability, often a consequence of the brittleness problem
- Humans suffer from a variety of cognitive limitations and biases that make it difficult to meet this expectation
- Undisciplined (or clumsy implementation of) automation can make the operator's situation more challenging

Source: T. Sheridan, J. Reason

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Key Points

- The engagement process must be operator-centric, even in highly automated systems
- Don't push automation too far into the operators' engagement decision making domain
  - Engagement decision making is the province of the human operator
  - Support the operator in making key engagement decisions and in supervisory control of more "rote" aspects of the process
  - Be brutally honest about machine reliability
- Facilitate developing situation-specific trust in automation
  - The automation will be "better" in some situations than others
- Understand that automation does not eliminate or reduce operator and crew training requirements
  - Automation changes operators' jobs and makes them more complex
  - Training for automated operations can be more complex and demanding

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Vincennes Incident: 1988

- *USS Vincennes* shot down Iranian Airbus
  - State-of-the-art air warfare combat system (Aegis)
  - Highly-trained crew, considered fully-capable
- Proper consideration of system design, training, personnel policies, and crew sensemaking is required for effective command and control

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Autonomous High-Altitude Refueling Demonstration Program

Mr. Jim McCormick

Program Manager, Tactical Technology Office

Briefing prepared for National Defense University
Unmanned Platforms: Implications of Mission Autonomy for U.S. Forces
May19, 2011

The views expressed are those of the presenter and do not reflect the official policy or position of the Department of Defense or the U.S. Government

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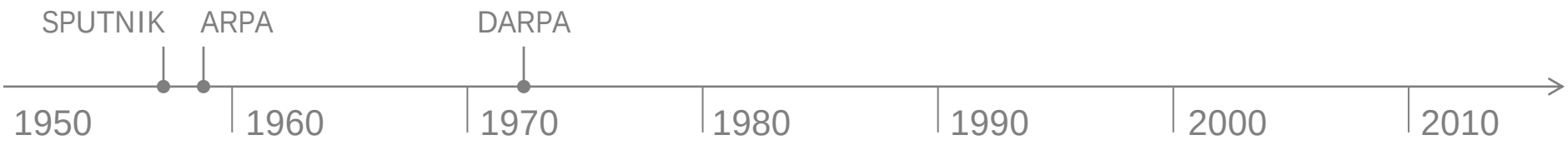

- Create and deny **surprise**
- Lean, agile organization with a **risk-taking culture**
- **Idea-driven** and outcome-oriented
- **Demonstrate** solution concepts

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AHR Motivation

- **Air refueling has proven an invaluable military enabler**
  - **DARPA has addressed UCAVs in a conventional tanker fleet**
  - **USAF, USN are implementing similar refueling capabilities for ongoing development programs**

DARPA Autonomous Air Refueling Demo (2005-2007): Demonstrated feasibility of autonomous probe-and-drogue in operational conditions using manned F-18 surrogate UAS

AFRL (2004-2013): Component development for unmanned Next Generation Long Range Strike

USN (2008-2015): Technology maturation for a Navy unmanned combat air system

- **High-altitude persistent unmanned aircraft address complex military needs**
  - **Feasibility of air refueling this class of aircraft has not been established**

- **UAV-to-UAV refueling is not possible today**
  - **Precision controls don't exist for HALE aircraft**
  - **Safe formation flight of unmanned aircraft has never been done**

AHR (2010-2012): Feasibility of refueling HALE-class aircraft in a challenging flight environment
- Global Hawk testbeds
- COTS refueling hardware
- Reverse fuel flow
- 45,000 ft, 135 kts indicated

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Background: DARPA AARD Program

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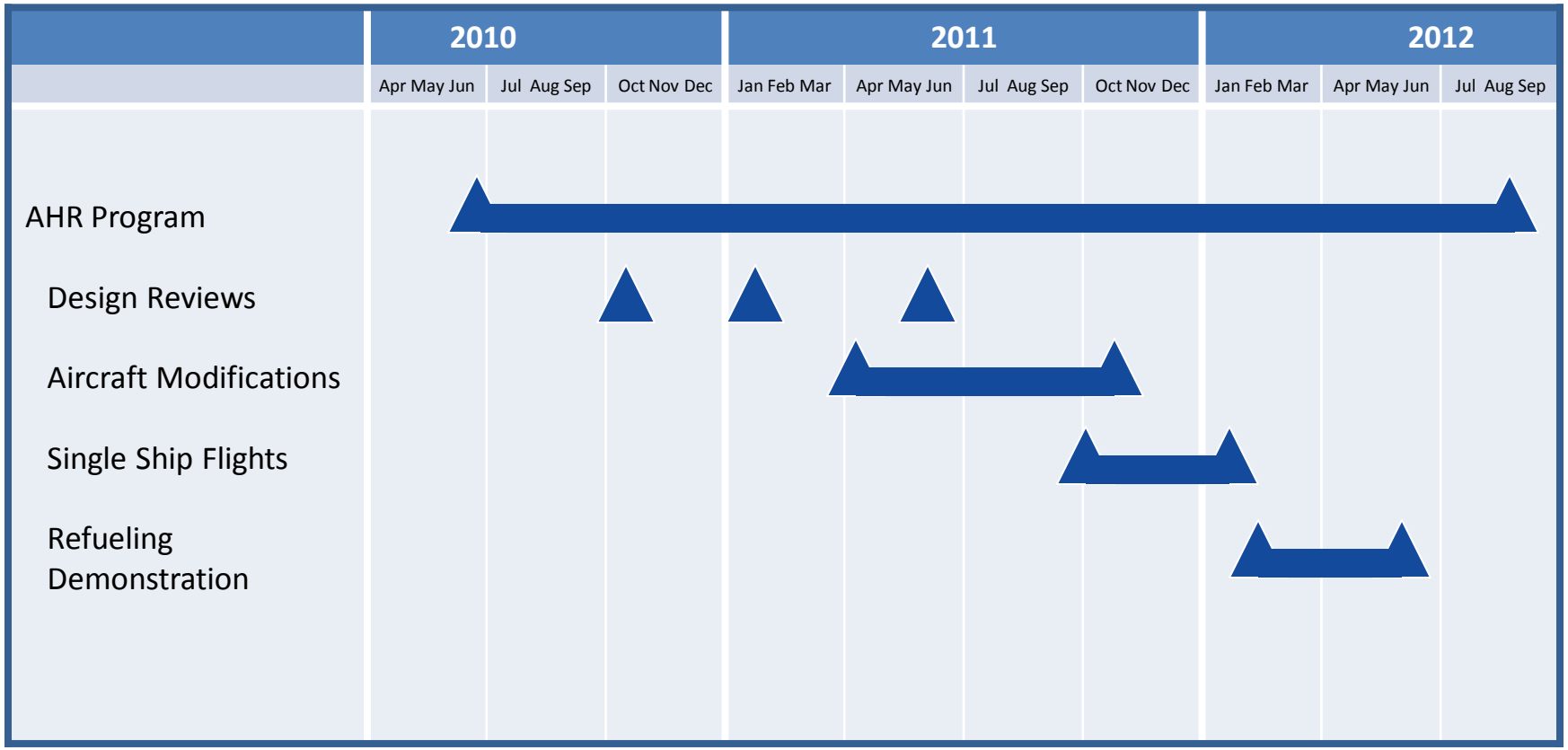
AHR Program Schedule



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AHR Wake Survey

- **8 Dec 2010 through 21 Jan 2011 - Wake survey flights: NASA King Air (low alt) and Scaled Composites Proteus (high alt) trailing a NASA/Northrop Global Hawk**
  - **Provided qualitative (pilot debrief) and quantitative (aircraft state data) evidence that AHR can safely and effectively achieve program objectives**
  - **Aircraft have never before flown in such close proximity (<40 ft nose to tail) at high altitude (45,000 ft)**

Global Hawk / King Air, 8 Dec 2010

Proteus / Global Hawk, 21 Jan 2011

"All objectives met with good results. The wake met expectations and Proteus was able to maintain the required positions. There was not a big altitude effect on the wake, however, Proteus throttle movement at 35K' or higher must be very low gain to avoid RPM exceedences."

(M. Stuckey, 24 Jan 2011)

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AHR Wake Survey

AHR Program Deliverables

- **Enable next generation HALE aircraft development based on refueling-capable approach**
  - **Demonstrate repeatable refueling capability across a range of ambient conditions**
  - **Representative fuel transfer: 3,000 pounds, 3 hours, 3,000 pounds**
  - **Capable of 7-day demonstration**

- **Technical products that may also be of value**
  - **Performance data**
  - **Measure of "Sufficient" equipage**
  - **Published technical papers**
  - **Potential for NASA residual refueling-capable aircraft**

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User / Industry Input Needed

User Input

- What kind of next-generation systems do you envision using these technologies?
- What will constrain your ability to use these technologies?
- What will these technologies allow you to do that you can't do today?
- How important are the capabilities that these technologies make possible:
  - Endurance?
  - Range?
  - Flexibility?
  - Continuity?
  - Availability?
  - Other?
- Who should we engage to discuss specific uses of this technology?

Industry Input

- What are the obstacles to using these technologies?
- How can the results of this program support future platform development?
- How important are the various attributes of these technologies:
  - Low cost?
  - Ease of use?
  - Safety?
  - R&M?
  - SWAP?
  - Other?
- What else needs to happen before these technologies are ready to start platform development?
- Who should we engage to discuss specific applications of this technology?

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www.darpa.mil

Transforming National Security Series Event

Unmanned Platforms: Implications of Mission Autonomy for U.S. Forces

Unmanned and Autonomous Systems (UASs) and Future Wars

19 May 2011

Al Sciarretta

Senior Research Fellow

Center for Technology and National Security Policy

National Defense University

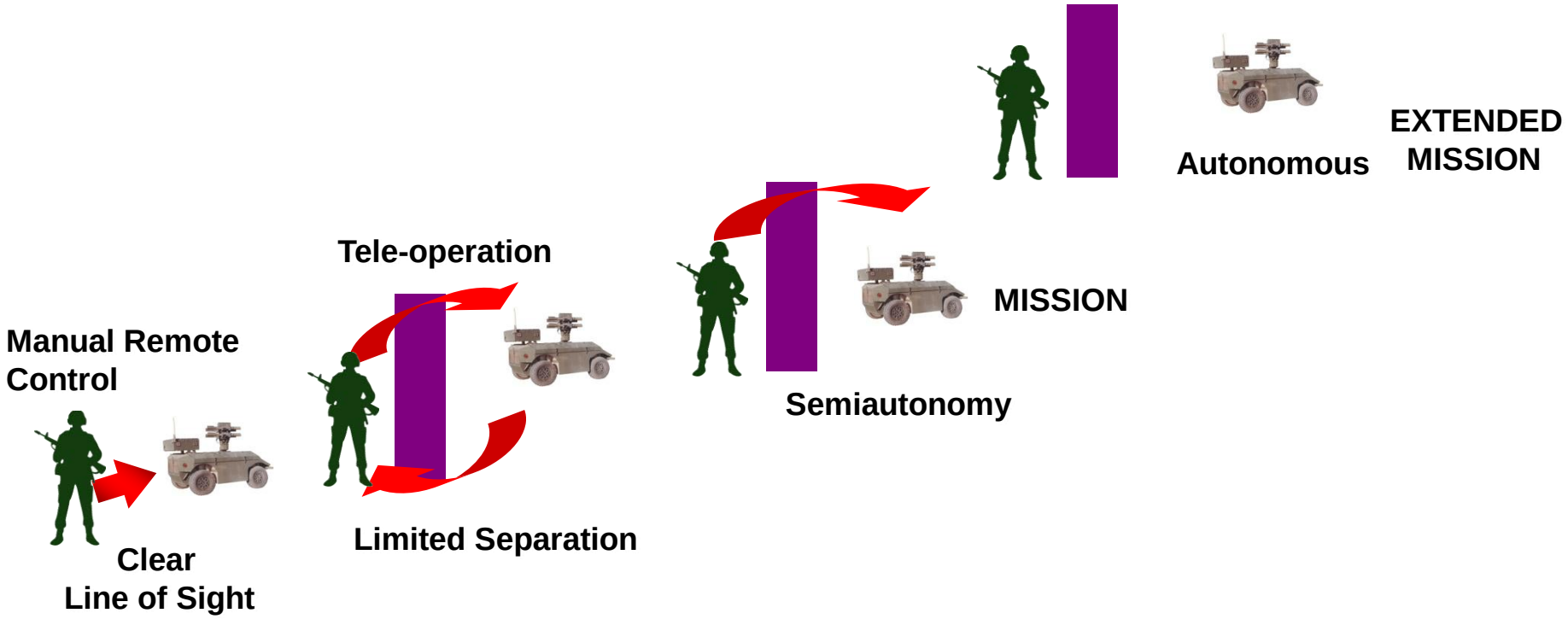
albert.sciarretta@ndu.edu

AI's Axioms

- As systems achieve intelligent autonomy, things usually seem to go wrong
  - HAL, Terminator, "VIKI" (Virtual Interactive Kinetic Intelligence)
- Bad often is developed with the good
  - Star Trek: Data and Lore
- The more a UAS achieves intelligent autonomy, the more it looks human
  - Terminator, Data, Sonny

Reference: Hollywood

Evolution of UASs



- 2001 goals:
  - by 2010, one-third of the aircraft in the operational deep strike force aircraft fleet are unmanned
  - by 2015, one-third of the operational ground combat vehicles are unmanned.

If We Meet Expectations

- Warfighters kept out of harm's way
- Unemotional warrior
- Sophisticated sensing beyond human Warfighter's capability
- No fatigue – 24 hr/day readiness
- Logistics impact reduced for food, water, and medical support; but increased for power and equipment resupply (especially if "throwaway")
- Cultural military shift
- Legal issues?

Legal Issues

- Deviant behavior
  - Learned by UASs – e.g., child's attack on UAS changes perception of child from non-combatant to combatant
  - Generated by human controllers
    - Used for criminal behavior (war crimes, stealing, etc.), to exploit other humans (intruding on one's privacy), or to use in "apparent" fun (e.g., gladiator fights)
- If a UAS commits a crime, is it the fault of the:
  - Commander
  - UAS
  - Human controller
  - Manufacturer of system
  - Manufacturer of software

  Note: Responsibility may vary with autonomy
- Will always want a "Warfighter-in-the-Loop"

Use of UASs in Small Unit Operations

- Need scalable autonomy and “looks” for regular and irregular warfare
  - Need to be conscious of cultural concerns
- Use in critical tasks (e.g., team clearing a room) is directly related to Warfighter trust in the system
  - May be a finite decision rather than a gradual increase
- Use will depend on fidelity of UAS capabilities
  - Cheaper, throwaway UASs used for detecting human in a room
  - More expensive UASs used for identification of a human
- Use in mission will depend on demands on operator
  - Higher the demands, the less use in missions that require a Warfighter’s attention – e.g., less use in offensive operations than in defensive operations
- Use should not detract from operator’s personal situational awareness

Threat Use?

- High tech adversaries
  - Will probably mirror our use
- Low tech adversaries
  - Ubiquitous use of UASs in commerce and entertainment translates to ease of access by low-tech adversaries
  - Will most likely use “improvised” UASs (IUASs)
- Big problem: Rogue UAS
  - High tech or low tech adversaries with little consideration for human life may use “rogue” UASs (and IUASs) which violate all three of Asimov’s laws
    - And have “dead man” switches to act as suicide bombers
  - Cyber attacks may change “good” UAS to rogue UAS

Questions?

Al Sciarretta

albert.sciarretta@ndu.edu

C: 703-517-2143

Expendable Platforms

Adrian Stoica
NASA Jet Propulsion Laboratory

Panel on New Strategies for Expendable Systems
National Defense University, Washington DC
May 19, 2011

Unmanned platforms at NASA

Space program

- Manned
- Unmanned
- Autonomy
- Cheaper – Taking higher risk of loss
- Expendable

Expendable platforms (EP)

A platform for which the cost of loosing it is *small*

- Low cost to produce/replace
- *Little or no loss of technological advantage*

  (non-compromising: low tech or anti-tamper)

Cheap to make means we can afford to do many, to operate new missions, to *take higher risks*

Small and light favors compact deployment of many

Accessibility (know-how & parts) and affordability ($k) of EP is on the rise – *<u>for everybody.</u>*

Adversarial groups, even small ones, could also develop/use EP to inflict significant harm on us

The power of many

Applications in ISR, communications, EW, engagement

- Nodes in multi-point coverage
  - distributed in wider area,
  - higher density/resolution
  - Ad-hoc networks
- Virtual apertures
- Higher system level reliability by redundancy
- If small, then easier to pack, deploy, harder to detect

Issues:

- Coordination/collaboration
- System-level reconfiguration

Persistent area surveillance

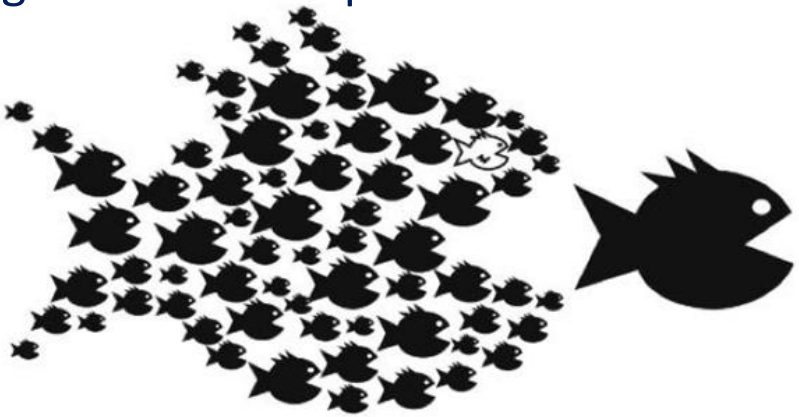
- Many sensors/devices allow:
  - Multiple perspectives
  - Robust sensing
  - Virtual Larger Systems
- Could move around to optimize coverage or better track events
- Can increase persistency of observation at low cost using lower lifetime low duty-cycled sensors with sleep algorithms.

In air, ground, at sea/underwater

May also be used to do science, e.g. to derive higher resolution models of the environment, which can be used advantageously during a conflict, for maneuvers, resources, or controlled as an asset

Group intelligence - swarm behaviors

- "Swarm intelligence": collective behavior of decentralized, self-organized systems.
  - Emergence (system has properties not present at the lower levels)
  - Stigmergy (traces of an action by an agent influences performance of next action by same/different agent)
- Simple rules (e.g topological)
- Limited sensing/communication
- Local (neighbor) interaction



Fundamental questions:

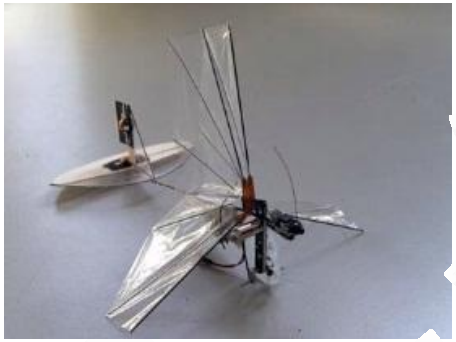
- How to control/predict swarm behaviors from individual behaviors
- How to achieve cooperation/collaboration inside swarm, with other swarms, same or different, and with humans

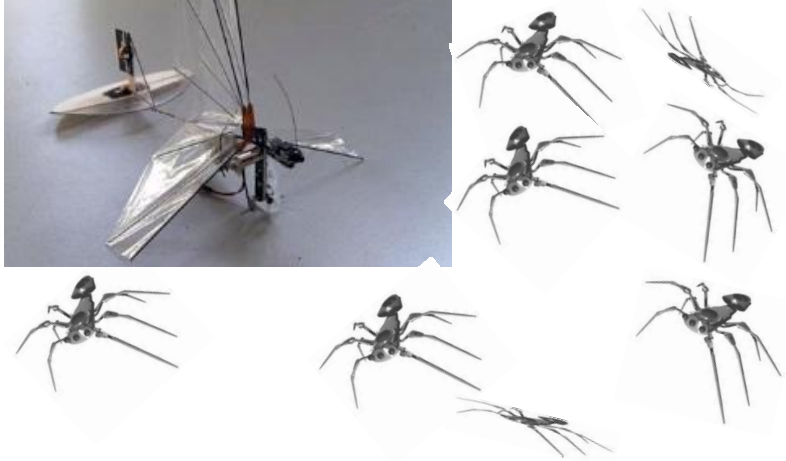
Reconnaissance

- EPs of all types
  - Conventional, all sizes
  - Micro/bio-inspired
  - Multi-modal (fly/walk, walk/ swim)
  - Transformers

- Scouts that interpret what they see
- Miniaturization allows them to <u>search/penetrate through smaller entries in restricted spaces (e.g. in command and control centers</u>)

- Many means better resolution in space and time





Swarms are good for search/scouting, can continue operation even if many of the individuals are disabled

Sacrificial platforms in “harm’s way”

Can act as a *deceptive avant-garde* of the attack

- To consume enemy resources
- To mislead enemy on the real intent. The swarms can “obfuscate” the true intent of actions, confusing/misleading the enemy. It is harder to infer the true goal state of a decentralized system because it requires longer/distributed observation history

Can be *an effective way to engage/overcome stealth defense systems*. For example, it can “draw fire” or otherwise activate the perimeter defenses.

This may provide a unique view into the enemy’s strategy, in a way that can not be done with passive/active ISR

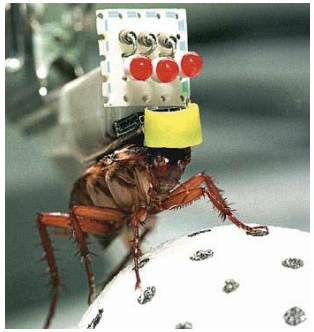
Other applications

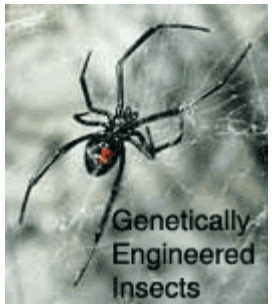
- In preparation of attacks: deploy EP in advance in enemy territory:
  - Energy/fuel or other resources, activated when needed
  - Location beacons in GPS denied areas

- In jobs with low sophistication, that do not require much intelligence: e.g. IED checks, mine neutralization

Expendable Bio-Systems

- Sensor carriers
- Computer controlled
- Genetically modified





In particular can be used as countermeasures for biochemical/chemical warfare: fighting back with bio-engineered or hybrid bio-mechanical units.

We do not fully understand the consequences

Security: protection against cyber attacks

Cheaper platform means ‘cheaper’ security measures

Susceptibility of Trojans

- Take measures to ensure trustworthiness

Large numbers means large number of entry points

- Built-in security
- Cross validate info provided from EP

Defense against cooperating attacks:

- Pervasive/infrastructure security, security standards, distributed anomaly detection, e.g. with spatially distributed swarms or in the context of network intrusion prevention
- Cooperative defenses (a “neighborhood watch” model)

Controls: centralized vs. distributed

- Centralized: with complete knowledge of state, you can device control algorithms with global stability/properties
- Without a centralized authority that collects all info,, you can achieve only local suboptimal results, and potential instability

- Distributed systems tend to be more resilient to failure
- Leader-based, e.g. elected by election
  - Info converges to leader, decision is broadcasted
  - killing leader may attract election overhead
- Fully decentralized: complete failures or Byzantine/arbitrary failures

- Important to understand HRI in the context of distributed systems

The human factor

- *EP absolutely depend on autonomy*. However, human is always involved even in fully autonomous systems.

- We need <u>more powerful human interfaces (maybe by exploiting more directly in biological signals – e.g. EMG/EEG)</u>
  - To control more platforms by a single operator - control the swarm
  - To shape the smarm (control to individual level)
  - To allow collaborative missions where each operator controls his team
- We need more intelligent autonomy
  - We want platforms to interpret and made decisions ('understand') on context for which they were not programmed before
  - Machine learning – machine that teach each other
- We want to better share situational awareness

Humans and what loop they are in

- UP replacing humans in activities humans do well
- UP extending human capability where humans DO NOT do well
  - Example: real-time virus attack – beyond capability of human to respond
    - Limits – in capability of attention, in memory, response time, etc
  - Human are in a loop:
    - Design loop, then
    - Verification loop, then
    - Specification loop…

Trends and consequences

- The higher cost of ES is in its physical part, but it goes down
- On-board intelligence costs going down with Moore's law
- Off-board intelligence costs going down with increased communication capabilities

This means that expandable systems will become increasingly intelligent AND when you destroy the body, you do not necessarily destroy the 'mind' (which can be 'passed' to another platform in the swarm).

Now, when you shoot down an airplane you take out 'body' and 'mind'. With expendable systems the 'mind' will be ported/reused.

Expendable systems are a force multiplier. The intelligence part is resilient.

Effects on force structure

- The next arm race may be in terms of weapon/defense intelligence, not raw power.
- Increased force projection via UP/EP
- Displacement of skills, analogous with loss of skill in semiconductor industry
- Needs for continuous training
- Expendable systems offer <u>more trade-offs between probability of mission success and cost</u>.

Final thoughts

- Learn from operations that effectively exploit many unmanned platforms, such as automated mining, where in a 24/7/365 operation the machines do much better than humans.
- Achieve interoperability without being monoculture/vendor driven
- Deal with psychological aspects, such as the acceptance of warfighter fighting remotely/via proxy
- Understand what we loose by becoming increasingly reliant on unmanned platforms
- Prepare fallback plans to deal with a major flaw in unmanned armies