Edited by
Nancy J. Cooke, Leah J. Rowe,
Winston Bennett, Jr and DeForest Q. Joralmon

Remotely Piloted Aircraft Systems

A Human Systems Integration Perspective

Aerospace Series
Editors Peter Belobaba, Jonathan Cooper and Allan Seabridge

WILEY

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Preface

Globally the news media, popular culture and private citizens are sensationalizing "drones." The term "drone" alone implies unmanned and autonomous. The reader will note that the editors of this book went to great lengths to deemphasize the term drone in favor of the more accurate term, Remotely Piloted Aircraft Systems (RPAS). RPAS represent a system of systems that rely on human inputs, interactions and operations. RPAS have also been referred to as Unmanned Aerial Systems (UAS), Unmanned Air Vehicles (UAV) and Remotely Piloted Aircraft (RPA). We chose the RPAS terminology to emphasize that these aircraft exist *within a system*, an incredibly complex system of systems. *Remotely Piloted Aircraft Systems: A Human Systems Integration Perspective* sets forth to fuse the practices of Human Systems Integration (HSI) with the complexity of RPAS.

For at least a decade, the human factors of RPAS has been the continued focus of a community of scientists, engineers and practitioners. Their efforts have been highlighted in various workshops, conferences and books and range from the design of effective ground control stations to crew coordination, spatial disorientation, supervisory control of multiple vehicles, soda straw views of camera feed, and training and selection. Much progress has been made, but this progress has given way to a different, more complex set of new HSI problems. For example, current pressing issues include the integration of RPAS into the national airspace, training and certification of civilian pilots, and the exploitation of sensor data from these platforms and concomitant privacy concerns. We explore these issues in detail in this book.

Many people confuse the discipline of Human Factors with HSI. HSI is more than Human Factors; it is human-centered systems engineering. Human Factors are typically narrow in scope and the methods within the discipline are best suited for smaller systems. HSI encompasses multiple domains. It provides a framework in which human capabilities and limitations across various dimensions are considered in the context of a dynamic system of people, technology, environment, tasks, and other systems with the ultimate goal of achieving system resilience and adaptation, approaching joint optimization. The human dimensions include human factors, manpower, training, personnel, safety, survivability, and habitability.

HSI also considers large multi-layered sociotechnical systems which is more than just the RPAS as an air vehicle, but includes the ground control station and crew, the related systems for maintenance, take-off and landing, training, and all embedded in a larger organizational structure such as the Department of Defense or Federal Aviation Administration. HSI considers simultaneous constraints and interoperability of all layers of the system and complex interactions. When system development does not consider the larger context even though

development of a local component may be optimized, the larger system is poised for failure. For instance, an interface to support control of an RPAS should not be designed without consideration of the systems to support communications of its position and sensor information. The difficulty is that this kind of systems thinking requires teams of multidisciplinary individuals working together toward a solution.

The book highlights the importance of the systems approach. We offer that such considerations of tradeoffs, interactions within the system, unintended consequences, emergent behaviors of complex systems, systems embedded in context, and the reduction of stovepipes are keys to successful system development and operation. A systems approach requires personnel from a variety of fields to collaborate and communicate to accomplish a common goal – a fully integrated system.

The book also provides a baseline definition for RPAS framed by the tenets of HSI. The editors strived to identify and collaborate with those most skilled in both the fields of RPAS and HSI. The authors of the chapters have varied backgrounds and experience to include military and civilian RPAS operators, industry professionals, governmental agency subject matter experts, and professionals from academia. Our hope is that with the vast perspectives covered in the text we will be able to shed some light on the intricacies of the HSI issues within RPAS.

The chapters in this book are inter-related and the order of the chapters is deliberate. We strongly recommend starting with Chapter 1 as it sets the terms of reference and the baseline for the entire book and provides important operational definitions that will be referred to throughout the text. The compilation of this book was a true collaborative effort across multiple disciplines. The editors would like to express our sincere gratitude to the authors who participated in developing this manuscript. Each and every single author spent countless hours collaborating within and across the chapter teams. These experts in their respective fields were motivated to provide a common operating picture to improve the HSI components of RPAS today and moving forward.

We would also like to thank the following individuals for their contributions in preparing the manuscript: Amanda Avenoso, Gary Rankin, Christine Covas-Smith, JoAnn Hamilton, Rachel Vickhouse and Katherine Wong at Wiley, and Garima Singh from Thomson Digital, were all helpful and responsive as we finalized this edition.

Author Biographies

Julie A. Adams
Dr Julie A. Adams is a Professor of Computer Science and Computer Engineering at Vanderbilt University where she leads the Human-Machine Teaming Laboratory. She earned her MSE and PhD in Computer and Information Sciences from the University of Pennsylvania. She holds a BS in Computer Science and a BBA in Accounting from Siena College. Dr Adams has over 115 refereed publications in the areas of multiple robot coalition formation, unmanned ground and aerial vehicles, human-robot interaction, human-computer interaction, and complex human-machine systems. She received the NSF Career Award and was a member of the DARPA Computer Science Study Panel. She is an associate editor for the IEEE Transactions on Human-Machine Systems, a senior editor of the Journal of Intelligent and Robotic Systems and serves on the editorial board of the Journal of Cognitive Engineering and Decision Making. Dr Adams served as a member of the National Research Council's Army Research Laboratory Technical Assessment Review Panel on Soldier Systems. She has served as the Vice President of Human-Machine Systems for IEEE Systems, Man and Cybernetics Society and currently serves on the society's Board of Governors. Dr Adams has served as co-chair of the Human-Robot Interaction Steering Committee and is the General Co-chair for the 2015 ACM/IEEE International Conference on Human-Robot Interaction. Prior to joining Vanderbilt, Dr Adams was an Assistant Professor of Computer Science at Rochester Institute of Technology. Before returning to academia, she worked in Human Factors for Honeywell, Inc. and the Eastman Kodak Company from 1995 to 2000. Dr Adams was also an Adjunct Professor in the Computer Science Department at the University of Rochester from 1999 to 2000.

Kristen M. Barrera
Kristen M. Barrera is a Research Psychologist at the Air Force Research Laboratory, 711th Human Performance Wing, Human Effectiveness Directorate, Warfighter Readiness Research Division in the Continuous Learning and Performance Assessment Branch. She is the principal for the Generalized Live, Virtual, and Constructive Training-Research Testbed where she leads researchers, engineers, and subject matter experts in the development of an operationally rich training research environment for military and civilian first responders. She holds an M.S.H.S. in Emergency and Disaster Management and is presently pursuing a doctorate degree in General Psychology. Her research interests include individual and team training and performance measurement.

Winston "Wink" Bennett, Jr.
Dr Winston "Wink" Bennett, Jr. is the Technical Advisor for the Warfighter Readiness Research Division located at Wright Patterson AFB Ohio. He is an Air Force Research Laboratory Research Fellow and a Fellow of the American Psychological Association. He is currently leading research developing methods to monitor and routinely assess individual and team performance across live and virtual environments and evaluating game-based approaches for training, work design, and job restructuring. Wink maintains an active presence in the international research community through his work on various professional committees and his contributions in textbooks, professional journal publications and related science and technology forums. He is an Associate Editor for the Journal of Military Psychology and serves on the editorial board for the Journal of Human Performance. He received his Ph.D. in Industrial Organizational Psychology from Texas A&M University in 1995.

John B. Bridewell
Dr John Bridewell is a Professor of Aviation at the University of North Dakota. He holds an Airline Transport Pilot certificate and has been a Certified Flight Instructor since 1972. He is the Director of the UND Center of Excellence for Unmanned Aircraft Systems Research, Education and Training and Assistant Chair of UAS for the Department of Aviation. Present research focuses on defining and refining training methodologies and technologies in cooperation with the Air Force Research Laboratory, 711th Human Performance Wing, Warfighter Readiness Research Division. He teaches undergraduate and graduate courses in manned and unmanned aircraft systems. Dr Bridewell is an active member and educational trustee for the University Aviation Association and promotes the development of remotely piloted aircraft systems research, education, and training within a collegiate aviation context.

Zane Brown
Zane Brown is a Subject Matter Expert, Consultant, Instructor Pilot and a Director of the Great Lakes Assessment and Research Enterprise (GLARE), a non-profit UAS consortium. He has over 30 years of aviation experience in matters relating to Aerospace, Airspace and Unmanned Aircraft Systems (UAS). Zane retired at the rank of Colonel in the USAF with an extensive background flying fighter and large transport category aircraft with USAF and NATO partner air forces. Along with his military background, Zane has over 22 years of civil aviation experience flying for a major airline. He has considerable experience in the areas of Flight Operations and the Command environment, Human Factors, Safety, Domestic Operations and Defense Support of Civilian Authorities (DSCA) missions as they relate to aviation. Zane spent several years specifically working issues on behalf of the State of Ohio regarding the civil use of UAS. He facilitated the stand-up of the Ohio/Indiana UAS Test Center, the development of the Ohio Department of Transportation's UAS program and spearheaded the use of UAS in Domestic Operations environments.

Kenneth T. Bruskiewicz
Ken Bruskiewicz, MA, is a Managing Research Scientist at PDRI, where he has directed many applied organizational research projects for a variety of government and private sector clients. He received his MA in Industrial and Organizational Psychology from the University of Minnesota in 1995. His primary research interests are in the areas of personnel selection, performance measurement, research methods, and statistics. Mr. Bruskiewicz is a two-time

co-recipient of the M. Scott Myers Award for Applied Research in the Workplace (2000 and 2012), awarded by the Society for Industrial and Organizational Psychology (SIOP). He has presented the results of his work to many professional and academic audiences, such as the American Psychological Association, the Society for Industrial and Organizational Psychology, the Military Testing Association, and the International Symposium on Aviation Psychology.

Gloria L. Calhoun
Gloria Calhoun (MA Human Performance) is a Senior Engineering Research Psychologist at the Air Force Research Laboratory. She began her career in 1974 as a support contractor. Her ensuing research on multifunction controls and display formats informed F-16 and F-18 platforms and others of today's "glass cockpits." In 1982, she began her Air Force career, evaluating several head-up, hands-free interfaces including spatial aural cues, eye line-of-sight control, speech recognition, and brain actuated control. Around 2002, her interface research focused on remotely piloted aircraft (RPA) control including more efficient speech-based control versus manually navigating menu pages, wrist-worn tactile display for alerts, and several applications of synthetic vision technology (e.g., expanding the effective camera field-of-view to mitigate the current "soda straw" view problem). In response to the Air Force's vision for more capable RPA systems, Ms. Calhoun then initiated research to address operator-automation interfaces. She led the design and evaluation of a temporal control/display tool and sense-and-avoid system interface. She also evaluated alternative automation schemes, including a direct comparison of performance-based adaptive versus adaptable automation. The results, besides highlighting control scheme trade-offs, suggested that operator personality influences automation usage. Her follow-on research also extended adaptable automation approaches to create a multi-level flexible control whereby the automation's role can be tailored to better support multi-RPA applications. Ms. Calhoun has authored over 120 publications, included 6 book chapters. She has served on several NATO/RTO groups and conference program committees, has held offices in professional chapters, and is an ad hoc reviewer for 8 journals. In 2013 she was elected for Fellow status in the Human Factors and Ergonomics Society.

Thomas R. Carretta
Thomas R. Carretta received a PhD in psychology from the University of Pittsburgh. He is a Senior Research Psychologist at the US Air Force Research Laboratory (AFRL) in the Supervisory Control and Cognition Branch of the Human Effectiveness Directorate and conducts research regarding human factors issues in human-system interface development for unmanned systems. He also acts as a consultant to the Air Force Personnel Center and Accession Policy on personnel selection and classification issues including test development and validation and the role of general and specific abilities in skill acquisition. He is the US Air Force technical representative to the Manpower Accession Policy Working Group which oversees issues related to military enlistment qualification, selection, and classification. His professional interests include personnel measurement, selection, classification, individual and group differences, and research methods. He is an editorial board member for the International Journal of Selection and Assessment and Aviation Psychology and Applied Human Factors and is a reviewer for several other journals. He has published over 80 journal articles and book chapters on topics related to these research interests.

Sharon Conwell

Dr Sharon Conwell, a member of the Air Force Research Laboratory, 711th Human Performance Wing, is a Senior Research Psychologist. She is responsible for Medical Research for Operations and Training. Between 2003-2012 Dr Conwell served as the head of organizational development for the 711th Human Performance Wing. Her responsibilities included policy and oversight of the organizational development plans, policies and programs that affected over 2000 Wing employees worldwide. Dr Conwell's portfolio spanned the full spectrum of organizational development to include: talent acquisition, development and sustainment, performance management, organizational change, strategic workforce and succession planning, leader development. Prior to her AFRL appointment, Dr Conwell served as the Deputy Director for Marketing and Strategic Planning in the Office of Citizen Services at the General Services Administration. In this role, she supported the Director of Citizen Services and the Director of GSA in formulating plans, policies and programs to manage the organization performance and reporting to the Office of Management and Budget. Before moving to GSA, Dr Conwell served as the Director of the Joint Recruiting Advertising Program for the Office of the Secretary of Defense overseeing the policy, planning, and execution of the office's multi-million dollar advertising program including television, radio, magazine, direct mail, billboard campaigns. She also served as the principal liaison for all military service recruiting commands to the Office of Accession Policy. In addition, Dr Conwell serviced as the liaison to the Office of Accession Policy for the Armed Services Vocational Aptitude Battery testing program for the Defense Manpower Data Center. Prior to federal civilian career, Dr Conwell was appointed as a Lieutenant in the U.S. Navy serving as the Chief of the Human Factors Branch in the Human Factors Division at the Naval Biodynamics Laboratory. Prior to her military career, Dr Conwell worked for 10 years at AT&T Communications. Dr Conwell has a Bachelors, Masters and Doctorate from Texas Tech University. Her professional military education includes Naval Officer Indoctrination School and Air War College and she is a graduate of the Senior Executive Fellows Program at Harvard University and the Advanced Management Program for CEO Grooming at the Wharton School, University of Pennsylvania.

Nancy J. Cooke

Nancy J. Cooke is a Professor of Human Systems Engineering at Arizona State University and is Science Director of the Cognitive Engineering Research Institute in Mesa, AZ. She is also currently the chair of the National Research Council's Board on Human Systems Integration, and President-elect of the Human Factors and Ergonomics Society. She recently chaired a study panel at the National Academies of Science on the Science of Team Science. Dr Cooke's research interests include the study of individual and team cognition and its application to the development of cognitive and knowledge engineering methodologies, cognitive task analysis, sensor operator threat detection, homeland security systems, remotely-operated vehicles, healthcare systems, and emergency response systems. In particular, Dr Cooke specializes in the development, application, and evaluation of methodologies to elicit and assess individual and team cognition. Based on her empirical work in her synthetic task environments for teams over the last two decades, Dr Cooke has proposed a theory of Interactive Team Cognition which is published (with Gorman, Myers, & Duran) in the journal, *Cognitive Science*.

Scotty D. Craig
Scotty D. Craig, PhD, is an Assistant Professor in the Human Systems Engineering Program within the Ira A. Fulton Schools of Engineering at Arizona State University. His goal is to provide cutting edge research at the intersection of human cognition, technology, and the learning sciences which provides solutions to real-world problems within education and training. His current research focuses on improving learning with higher-level cognition factors such as metacognitive scaffolding, discourse, and cognitive affective support through the use of technology-based learning environments (e.g. virtual humans, virtual worlds, etextbooks, tutoring systems, and video). His current academic contributions include over 70 publications (journal articles, book chapters, and proceedings), 48 presentations, guest editor for three journal special issues, and one edited book: Readings in Training and Simulation (Fall, 2015). More information on his current work can be found on his lab website, www.cobaltlab.org.

John R. Dougherty
Colonel John R. Dougherty (BS Electrical Engineering/Computer Science) is the 119th Operations Group Commander for the 119th Wing, North Dakota Air National Guard. As Commander, he is responsible for over 220 Airmen and two separate flying missions supporting Air Combat Command and Air Mobility Command. As an MQ-1 Predator pilot, he is engaged in ongoing missions supporting Intelligence, Surveillance and Reconnaissance operations for combatant commanders. He also consults on matters relating to Aerospace, Airspace, and Remotely Piloted Aircraft Systems. Colonel Dougherty began his military career by enlisting in the 119th FIW, North Dakota Air National Guard in 1984. He was commissioned in 1985 and was subsequently selected to attend Navigator Training where he was a distinguished graduate and became an F-4D Weapons System Operator for the 178th FS. After accumulating over 500 hours in the Phantom, he was selected to attend Pilot training where he graduated top in his class. Following F-16 training, he returned to North Dakota rejoining the 178th FS. Over the next 16 years he served numerous positions within the squadron and wing to include the Director of Operations for the 178th FS and accumulated 2500 hours of F-16 flight time. When the 119th Wing converted to the MQ-1, he was part of the initial unit cadre and has flown over 1400 hours of combat support in this airframe. He served as the 119th Operations Support Squadron Commander and 119th Operations Group Deputy Commander prior to his current position. Colonel Dougherty is a command pilot with more than 3500 hours in eight aircraft. He has received numerous awards and decorations. He is an academic award winner, as well as a Distinguished Graduate of Pilot training, Navigator training, and MQ-1 training. Decorations include the Aerial Achievement Medal, Air Force Commendation Medal, Air Force Achievement Medal, Air Force Outstanding Unit Award, and Air Training Command Commanders Cup Trophy-Pilot training.

Claude Ezzell
Claude Ezzell's career began in the Army in the Military Police Corps. After his initial enlistment he joined the Air National Guard as an Intelligence Analyst working in Imagery Analysis. When not working as a reservist he worked in Correctional Medicine and eventually as a Civil Service Firefighter for the Federal Fire Department specializing in Emergency Medical Services. After moving to Arizona in 2003 his military career took a dynamic turn with a newly formed Remotely Piloted Vehicle program where he was employed as a Sensor Operator and Security Manager. Subsequent assignments included temporary duty with the Air

Force Research Laboratory as an Intelligence Specialist where he worked in C4ISR research and as a Mission Planning Chief for other reconnaissance missions. In 2009 he was assigned to UAV Flight Testing at Edwards Air Force Base evaluating sensor development. Upon retirement from the military he accepted the position as an Advanced Geospatial Intelligence Analyst at the Army Theater Ground Intelligence Center and Instructed Career Army Intelligence Officer in the field of Geospatial Intelligence at Fort Huachuca, Arizona. At Holloman Air Force Base he operated the Predator Mission Aircrew Training System conducting dynamic flight simulations for aircrews in training. Moving on, he currently oversees Security Management in an Air Force RPA Flight Test Squadron.

Keven Gambold

Keven Gambold completed a BSc in Psychology and Philosophy at Durham University, England and attended Royal Air Force Officer Training in 1992. After flying training on T-37B, T-38A and Hawk T Mk1, he was posted to the Tornado GR4. During 2 tours on the aircraft, Keven participated in OP WARDEN (Turkey), OP BOLTON (Kuwait), OP ENGADINE (Kosovo), where he was awarded a Mention in Dispatches, and OP IRAQI FREEDOM, launching the Storm Shadow Air-Launched Cruise Missile. He was the Squadron Electronic Warfare Instructor, Laser Targeting Pod lead, a 4-ship lead, Instrument Rating Examiner and the Training Officer. With full Electro-Optical qualifications he completed the Tactical Leadership Program, Maple and Green Flags and 14 months in Kuwait. Keven completed his tour with over 1500 hours on the Tornado fleet. Keven volunteered for the Combined Joint Predator Task Force in April 2004 and was posted to Nellis and Creech Air Force Bases, Nevada, USA. Whilst working on the Predator, Keven logged over 1500 hours combat flying, with two deployments to Launch-Recovery Elements, the second as the inaugural Squadron Commander at Tallil Air Base, Iraq. As Chief of Standards & Evaluation, he wrote and mentored UAS standards, novel CONOPs and training packages. Keven was fortunate enough to lead the trials and introduction to service of the first ever Multi-Aircraft Control (MAC) systems. Additionally he was a member of the cross-industry Advanced Cockpit Working Group, undertaking numerous surveys of current practices and standards to assist in software spiral developments and cockpit improvements. In his past role as Director for the Guild of Air Pilots and Air Navigators (North America)'s Technical Aviation and Safety Committee, Keven has published peer-reviewed papers on UAS operations in the civil sector. In addition, he was an active member of (the late) RTCA SC-203 and SC-228. Keven has chaired several global UAS Conferences and Workshops and has written and broadcast numerous Webinars. Keven has also written, and taught numerous international UAS training courses. He holds a JAA Commercial Pilots License, a Masters in Aeronautical Science (Aeronautics Operations) from ERAU and is a member of AUVSI, Chartered Management Institution, The Air League, RTCA, AOPA and SAFE. Keven is married and lives in the USA with his wife and young family and two rescue kittens. He was a founding member of Unmanned Experts Inc. and holds the position of Chief Executive Officer of this global consultancy and training firm.

Valerie Gawron

Valerie Gawron has a BA in Psychology from the State University College at Buffalo, an MA also in Psychology from the State University College at Geneseo, a PhD in Engineering Psychology from the University of Illinois, and a MS in Industrial Engineering and MBA both from the State University of New York at Buffalo. She completed postdoctoral work in

environmental effects on performance at the New Mexico State University in Las Cruces and began work for Calspan directly following. She remained at Calspan for 26 years until it was eventually acquired by General Dynamics and she was made a technology fellow. She is presently a human systems integrator at the MITRE Corporation. Dr Gawron has provided technical leadership in Research, Development, Test, and Evaluation of small prototype systems through large mass produced systems, managed million dollar system development programs, led the design of information systems to support war fighters and intelligence personnel, fielded computer aided engineering tools to government agencies and industry, tested state-of-the-art displays including Helmet Mounted Displays, Night Vision Goggles, and Synthetic Vision Displays in military and commercial aircraft, evaluated security systems for airports and United States Embassies, conducted research in both system and human performance optimization, applied the full range of evaluation tools from digital models through human-in-the-loop simulation to field operational tests for military, intelligence, and commercial systems, directed accident reenactments, consulted on driver distraction, accident investigation, and drug effects on operator performance, and written over 410 publications including the Human Performance, Workload, and Situation Awareness Measures Handbook (second edition) and 2001 Hearts: The Jane Gawron Story. Both of these are being used internationally in graduate classes, the former in human factors and the latter in patient safety. Dr Gawron has served on Air Force Scientific Advisory Board, the Army Science Board, Naval Research Advisory Committee, and National Research Council. She gives workshops on a wide range of topics to very diverse audiences from parachute testing given as part of the Sally Ride Science Festival for Girls ages 8 to 14 to training applications of simulation to managers and engineers. She has worked programs for the United States Air Force, Army, Navy, Marines, NASA, the Departments of State and Justice, the Federal Aviation Administration, the Transportation Security Administration, the National Transportation Safety Board, the National Traffic Safety Administration, as well as for commercial customers. Some of this work has been international and Dr Gawron has been to 195 countries. Dr Gawron is an associate fellow of the American Institute of Aeronautics and Astronautics, a fellow of the Human Factors and Ergonomics Society, and a fellow of the International Ergonomics Association.

Michael A. Goodrich

Michael A. Goodrich received his BS, MS, and PhD in Electrical and Computer Engineering from Brigham Young University in 1992, 1995, and 1996, respectively. From 1996-1998, he was a post-doctoral associate at Nissan Cambridge Basic Research, a lab sponsored by Nissan Motor Company in collaboration with professors from MIT and Harvard. In 1998, he joined the Computer Science Department at Brigham Young University where he is now professor and chair. His research has addressed a wide range of human-machine interaction topics including wilderness search and rescue operations with unmanned air vehicle technologies, assistive robotics technologies to help treat children with autism, and multi-agent management and learning. His current research emphasis is on human-robot interaction for teams of humans interacting with teams of robotic air and ground vehicles. He has published over one hundred peer-reviewed papers in multiple areas including human-robot interaction, artificial intelligence, machine learning, and decision theory. He is a reviewer for ten journals and has served on many Technical Program Committees. In particular, he has been a key organizer for the ACM/IEEE International Conference on Human-Robot Interaction. His work has been funded

by the National Science Foundation, Defense Advanced Research Projects Agency, Office of Naval Research, Army Research Laboratory, Honda and Nissan. His favorite type of research involves multi-disciplinary efforts, which has led to publishing and submitting funding proposals with co-authors from engineering, psychology, cognitive science, communication disorders, philosophy, business, and contemporary dance.

George Harrison
George Harrison is Associate Director, Georgia Tech Research Institute, Atlanta, Georgia. Before his retirement from the US Air Force in July 1997 as a Major General, he was Commander, Air Force Operational Test and Evaluation Center, Kirtland Air Force Base, New Mexico. George began his Air Force career as an F-4 pilot at MacDill AFB, Florida in 1963. Since then, he has flown combat in the O-1F from DaNang AB, Republic of Vietnam (RVN), and the F-4 from Cam Rahn Bay AB, RVN and Udorn Royal Thai AFB. In later years, he flew combat missions in the F-16C over Iraq (Provide Comfort), the C-130E, E-3A and E-8C over and into Bosnia (Deny Flight and Joint Endeavor) and the E-3B over Iraq (Desert Storm). He commanded the 4485th Test Squadron, the 479th Tactical Training Wing, the USAF Air Warfare Center, Joint Task Force Southwest Asia and served as the Director of Operations for US Air Forces in Europe. George is an active civil aviator and is an FAA instructor in single and multiengine airplanes, instruments and gliders. His first solo was as a teenager in the Piper J-3 and now has logged over 8600 hours in 103 types of civil and military aircraft, including 530 hours in combat. An Airline Transport Pilot, he is experienced in conventional and tail wheel aircraft and gliders and is type-rated in the Boeing 707/720, Lear Jet, and T-33. George has a BS degree from the USAF Academy and an MBA from Wharton, University of Pennsylvania.

Phyllis E. Johnson
Phyllis E. Johnson received BS and PhD degrees in chemistry from the University of North Dakota. She was the Vice President for Research and Economic Development at the University of North Dakota from 2009–2014, and is currently a Visiting Professor at Concordia College, Moorhead, MN. She was formerly a Senior Executive at the United States Department of Agriculture, including 13 years as the Director of the Beltsville Agricultural Research Center, the largest and most comprehensive USDA research facility. She was recognized by President William J. Clinton with the Presidential Rank Award of Meritorious Executive. She has also been a Research Associate at the Smithsonian Institution and represented the US government at international science policy meetings, and is currently a member of the National Invasive Species Advisory Committee. Dr Johnson is the recipient of a number of awards for both research and technology transfer, including three from the White House.

DeForest Q. Joralmon
DeForest Q. Joralmon was a Senior Research Scientist for L-3 Communications, Link Simulation and Training Division, working under contract to the Warfighter Readiness Research Division of the Air Force Research Laboratory. He holds a Bachelor of Science Degree in Telecommunications from Northern Arizona University, a Master of Mass Communication Degree from the Walter Cronkite School of Journalism and Telecommunication at Arizona State University, and a PhD in Curriculum and Instruction from Arizona State University. His recent work is centered on conducting research and development of Remotely

Piloted Aircraft, Joint Terminal Attack Controller, and Air Support Operations Center training rehearsal systems for the Integrated Combat Operations Training-Research Testbed. He also conducts Joint and Coalition Training, Rehearsal, and Exercise research. He has previously conducted applied research and development in the use of advanced multimedia instructional technologies and specifically produced interactive multimedia curriculum used for US Department of Defense night vision device warfighter training.

Matthew J. Martin
Lt Col Matt Martin is an MQ-9 pilot and leads the Advanced Capability Team within the 28th Bomb Wing at Ellsworth AFB, SD. The team works to improve the fidelity, complexity, and efficiency of combat air force training through simulator-based distributed mission operations, improved live-fly threat simulations, hi-bandwidth tactical datalinks, and the implementation of the expanded Powder River Training Complex. Lt Col Martin received his commission via ROTC at Purdue University in 1994 and completed Undergraduate Navigator Training at Randolph AFB, TX. He has served in a variety of flying and staff positions to include: Commander, 46th Expeditionary Reconnaissance Squadron, Balad Air Base, Iraq; MQ-1/9 Operations Manager at Headquarters Air Combat Command, Langley AFB, VA; 49th Wing Chief of Safety at Holloman AFB, NM, and Commander, NATO Joint ISR Task Force Unified Vision 2014. Prior to his current assignment, Lt Col Martin served as the Chief of Airborne Reconnaissance and Electronic Warfare at Headquarters Allied Air Command Izmir, Turkey where he supervised all NATO and Coalition southern-region reconnaissance and electronic warfare operations from Portugal to Turkey, an area of responsibility that included 14 NATO nations, eight command headquarters, and spanned over three million square miles. Lt Col Martin is a Master Navigator, remotely-piloted aircraft senior instructor pilot, FAA Certified Flight Instructor, and Civil Air Patrol evaluator pilot with more than 4,000 hours in T-34C, T-43A, TC-135S, RC-135U/V/W, RQ-1A, MQ-1B, MQ-9A, and various general aviation aircraft.

Barry Milavetz
Dr Barry Milavetz, a tenured professor, joined UND in 1986 as a faculty member in the Department of Biochemistry & Molecular Biology, which is now part of the newly formed Department of Basic Sciences. He has served at University of North Dakota as the interim director of the Office of Research & Program Development from 2004 to 2005 and as the associate vice president for research and economic development from 2005 to 2015; during that time, he also served as the interim vice president for research and economic development from 2008–2009 and 2014–2015. As the associate vice president, he is responsible for the oversight of pre- and post-award administration of grants and contracts, maintaining compliance with research regulatory requirements, and supporting faculty program development. Milavetz also chairs many of the UND research compliance committees and was instrumental in the formation of the country's first Unmanned Aircraft Systems (UAS) Research Compliance Committee. He is currently writing a book chapter on policy issues related to the use of UASs.

John Jay Miller
John Jay Miller is Academic Affairs Officer in the Office of the Provost and Vice President for Academic Affairs at the University of North Dakota. He received a Juris Doctor and a Bachelor

of Science in Business Administration from University of Kansas. His previous experience was as a former prosecutor and as in-house counsel for municipal corporations in the State of Kansas. He is licensed to practice law in the State of Kansas and North Dakota.

Kelly Neville
Dr Kelly Neville is a Research Psychologist for the Naval Air Warfare Center Training Systems Division (NAWCTSD). She earned her MA and PhD in Experimental Psychology from Rice University. Her BA, also in Psychology, is from Trinity University. Dr Neville has a rich experience base in research and design aimed at enhancing human and team performance in complex systems. She specializes in proficiency and expertise acquisition, training system design, supporting cognitive performance in high stress work, and improving team coordination in complex work domains. Her work in these areas extends across a number of domains, including satellite operations, military command-and-control, US Marine Corp combined arms operations, air combat, petrochemical operations, and remotely piloted aircraft systems (RPAS). A related area of interest is complex systems and their resilience, and the improvement of systems engineering methods to better support the design and development of resilient complex systems.

Hans M. Poole
Lieutenant Colonel Hans Poole joined the Air Force in October of 1988. During his career, he has served as an Aircraft Crash Rescue Fire Fighter, Instructor Electronic Warfare Officer, Instructor Navigator, and RPA FTU Instructor Pilot. He has participated in Operations Desert Shield, Desert Storm, Iraqi Freedom, Enduring Freedom and multiple assignments to Joint Task Force Bravo. Currently he is a Flight Commander for the 108th Attack Squadron, MQ-9 RPA Formal Training Unit. Lieutenant Colonel Poole's civilian education includes a Bachelor of Science degree in Aeronautics with dual majors in Aircraft Maintenance and Professional Piloting from Parks College of Saint Louis University in 1996 and a Master of Science in Aeronautics from Embry-Riddle Aeronautical University in 2007. He is a Certified FAA Airframe and Power Plant Mechanic and holds an FAA Certified Commercial Instrument Pilot License. During his time with Air Force Education and Training Command he directed execution of three undergraduate flying training programs. His contributions to military training garnered him the 19th Air Force Instructor EWO of the Year, 563rd FTS Instructor of the Year and the AETC 2005 Modeling and Simulation Award. His flight experience includes 194 combat hours, 2,609 combat support hours, 1,262 MQ-9 hours, 1,586 MQ-1 hours, 184 T-43 hours, 1,563 MC-130H hours as well as 440 hrs in light civil aircraft as a FAA certified commercial instrument pilot.

John P. Riganati
Dr John P. Riganati is currently a senior technical advisor engaged in technical and business consulting services. He retired from Sarnoff Corporation (formerly RCA Research Laboratories) in December 2010 where he had served as Vice President and CTO and Vice President, Strategic Programs. Previously, he was the Director of Systems and Architecture Research at IDA's Supercomputing Research Center, Division Chief at NBS, and Chief Scientist at Rockwell International. He served as the Computer Society's representative to the IEEE Standards Board, was responsible for the Data Encryption Standard, as well as the creation of a Public Key Infrastructure [while at NBS] and the automation of the FBI's Identification

Division [while at Rockwell]. He was a member of the Air Force Scientific Advisory Board (AFSAB) (2008–2012), has served as an elected member of the IEEE Computer Society's Board of Governors, created the Computer Society's Seymour Cray Award, is cofounder of the international peer-reviewed *Journal of Supercomputing*, founded *Computing in Science and Engineering*, has been a Computer Society Distinguished Lecturer and has been a member of LLNL's External Advisory Board for thirty years. He received a Bachelor of Electrical Engineering degree (with highest honors), an MS in Electrical Engineering, and the PhD in Electrical Engineering with a minor in Mathematics from Rensselaer Polytechnic Institute.

Mark R. Rose
Dr Mark R. Rose is a Senior Personnel Research Psychologist with the US Air Force Personnel Center Headquarters (HQ AFPC). He received his PhD in industrial-organizational psychology from the University of South Florida in 1997. His research focuses on selection and classification, personality and ability measurement, and research methods. His recent research includes a review of unmanned aircraft selection practices across services, validation of measures for selecting unmanned aircraft pilots and sensor operators, and an investigation of the relative validity of distinct spatial abilities for predicting pilot performance. Dr Rose's work has been instrumental in making enhancements to the US Air Force's procedures and methods for selecting enlisted and officer applicants into specific Air Force training programs. His role involves occupational needs analysis, test development and validation, and serving as a technical advisor to Air Force leaders on selection system implementation. Prior to the Air Force, Dr Rose was a Research Director with Pearson, where he developed and validated selection and assessment tools. In addition to his full-time position, Dr Rose is currently adjunct faculty in the graduate I-O program at St. Mary's University-SA, where he teaches courses on Employment Law and Group Dynamics.

Leah J. Rowe
Dr Leah J. Rowe is a Senior Research Psychologist for the Warfighter Readiness Research Division with the Air Force Research Laboratory's Human Effectiveness Directorate at Wright Patterson AFB Ohio. She is the Branch Technical Advisor in the Continuous Learning and Performance Assessment Branch where she leads researchers, engineers, and subject matter experts in training effectiveness research. Dr Rowe and her team execute research in performance evaluation, team training, team coordination, instructional design, and quantifying the impact of training interventions. Dr Rowe received her MS in Applied Psychology and PhD in Industrial and Organizational Psychology.

Scott Scheff
Scott Scheff has a BA in Psychology from the University of Arizona, and a MA in Human Factors and Applied Experimental Psychology from California State University Northridge. Mr. Scheff is currently CEO and a principal Human Factors Engineer at HF Designworks, Inc., in Boulder, Colorado. Mr. Scheff has formal training in human factors design, user experience research, user interface design, human computer interaction, and system safety. Mr Scheff's vast multidisciplinary experiences span both the commercial and government sectors, implementing user-centered design in the development of software and hardware for both small-scale and large-scale products. These products include design and development of wearable computers for Army infantrymen, visualization techniques for managing large

amounts of data, blue force tracking for ground vehicles, unmanned vehicle command and control systems, as well as a host of medical and consumer devices. Mr Scheff has worked programs for the United States Army, Navy, Marines, NASA, Department of Homeland Security, and DARPA; as well as commercial customers both within the United States and international.

Lawrence G. Shattuck
A native of Lindenhurst, New York, Colonel Lawrence G. Shattuck (US Army, Retired) graduated from the United States Military Academy in 1976. His military service spanned thirty years with assignments in the United States and overseas, including Operations Desert Shield and Desert Storm. During his last ten years on active duty, he served as the Director of the Engineering Psychology Program at the United States Military Academy. Upon his retirement from the Army, he was appointed as a Senior Lecturer in the Operations Research Department at the Naval Postgraduate School where he directs the Human Systems Integration Program and serves as the Chair of the Institutional Review Board. He holds a Master of Science degree from Rensselaer Polytechnic Institute in Human Factors Psychology and a PhD from the Ohio State University in Cognitive Systems Engineering. He has been an active researcher in the domain of military command and control for two decades. Most recently, he has served as the architect for the Naval Postgraduate School's Human Systems Integration Certificate Program and the Distance Learning Master of Human Systems Integration Program. He is married to Nita Lewis Shattuck, PhD, an Associate Professor at the Naval Postgraduate School.

Jay Shively
Jay Shively is currently the Human Systems Integration Lead for NASA's UAS Integration into the NAS project. In this role, he leads a multi-disciplinary team across four NASA research centers to address barriers impeding the integration of UAS. To serve in this role, Jay transitioned to NASA after 25 years with the US Army. During his tenure with the Army, Jay was the Human Systems Integration group leader for the Aeroflightdynamics Directorate. In that role, he coordinated efforts on helicopter brown-out symbology, UAS ground station design, and cockpit design issues. Mr. Shively has published numerous papers, book chapters and conference presentations.

John E. Stewart
Dr John E. Stewart received his PhD in social psychology from the University of Georgia in 1973. He was an assistant professor at Mercyhurst University from 1973 until 1979, and a research analyst and consultant for the State of Arizona from 1980 until 1984. His career as an aviation psychologist began in 1984 at the US Air Force Human Resources Laboratory (now Air Force Research Laboratory) in Mesa, AZ. From 1985 until retirement in 2014 he served as a research psychologist and team leader for the Army Research Institute for the Behavioral and Social Sciences (ARI), first, in the manpower-personnel integration (MANPRINT) group in Alexandria, VA, and later at the ARI Aviation Research Unit at Fort Rucker, AL. Dr Stewart's many research efforts have included HSI integration of the Aquila unmanned aircraft system, evaluation of efficiency and effectiveness of simulation-augmented training systems for Air Force and Army Aviation, and adaptation of locus of control scales to risk orientation and involvement in hazardous events among Army aviators. His most recent efforts focused on

identifying, measuring, and training critical team-level scout reconnaissance skills for crews of both manned and unmanned aircraft.

Howard M. Weiss
Howard M. Weiss is a Professor in the I/O program and Chair of the School of Psychology at Georgia Tech. He is a SIOP Fellow, has been elected Fellow in both APA and APS, and is a former member of the National Research Council's Board on Human-Systems Integration (BoHSI). Weiss' research focuses on the experience of working, especially in an immediate, first-person sense. This includes interest in momentary emotional states, immediate focus of attention, boredom, mind wandering, and so on. He has served on the editorial boards of Organizational Behavior and Human Decision Processes, the Academy of Management Review, Motivation and Emotion, Personnel Psychology and the Journal of Management. His research has been funded by the Army Research Institute, the Office of Naval Research, the Department of Defense and the Spencer Foundation.

Kevin Williams
Dr Kevin Williams is a research psychologist at the Federal Aviation Administration's Civil Aerospace Medical Institute (CAMI) in Oklahoma City, OK. Prior to joining the FAA in 1992, Dr Williams worked in the Human Factors Engineering group at General Dynamics in Fort Worth, TX and was also team leader of a MANPRINT evaluation team during the operational test of an unmanned aerial vehicle (the Hunter system). Since joining CAMI, Dr Williams has been involved in the development of training device specifications for Personal Computer-based Aviation Training Devices (PCATDs), GPS design issues, and research on advanced primary flight displays. He is currently involved in research on human factors and pilot qualification and training issues of unmanned aircraft systems. He has written several technical reports and two book chapters related to unmanned aircraft systems and he has been involved in several standards groups including RTCA SC-203, RTCA SC-228 and SAE-G10.

1

Human Systems Integration for Remotely Piloted Aircraft Systems

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1.1 What is HSI?

Drones have received much attention in the press and the topic can stir up many debates about privacy, safety, and asymmetric warfare. Also referred to as Unmanned Aerial Vehicles (UAV) or Unmanned Aerial Systems (UAS) or Remotely Piloted Aircraft Systems (RPAS), they are not really unmanned, but instead, operated by many humans who serve as pilots, sensor operators, maintainers, and mission planners. As a possible side effect of the tendency to forget about these humans, the focus has too often been on the technology and not the human components of the system. The purpose of this edited volume is to highlight the human components of these systems, their interactions with the technology and each other, and the implications of human capabilities and limitations for the larger system. A Human Systems Integration (HSI) perspective is taken that considers humans as part of a large and interconnected system of technology, humans, and other systems.

In 2006 an edited volume was published by Elsevier on *Human Factors of Remotely Operated Vehicles* to which many of the authors of chapters in this volume contributed (Cooke *et al*. 2006). Topics included traditional human factors issues such as supervisory control, errors, human-machine interface issues, control of multiple vehicles, and team control. Nearly 10 years later we are revisiting some of these same topics, within a new landscape of RPAS that includes a much wider variety of systems and applications including civilian applications and plans to integrate these vehicles into the National Airspace System (NAS). It is acknowledged that the landscape has further changed between the completion of the writing of this book and its publication. In addition, many of the topics addressed in the 2006 volume were addressed in a piecemeal fashion. For example, a display may be designed with a synthetic overlay of target waypoints,

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which is intended to enhance the operator's situation awareness, only to raise other issues such as increased screen clutter, increased workload, and new training and selection demands. In other words, failure to consider the whole system and the complex interactions of its human and machine components, along with many different aspects of human concerns, can have unintended consequences. This perspective is known as HSI.

HSI is a framework in which human capabilities and limitations across various dimensions are considered in the context of a dynamic system of people, technology, environment, tasks, and other systems with the ultimate goal of achieving system resilience and adaptation, approaching joint optimization. The human dimensions considered include human factors, manpower, training, personnel, safety, and occupational health, environment, survivability, and habitability (Durso et al. in press; US Air Force 2009). The HSI environment includes not only the physical, operational, and technological aspects of a mission but also the economic, political, and social components. For RPAS, these last three are critical as numerous and diverse civilian applications promise enhanced economic gain while being debated on safety and privacy concerns. Although survivability is less of a concern in the use of drones, rocket launch systems as well as manual recovery systems have resulted in injury to crews. HSI is not the same as human factors, though one dimension of HSI is human factors. The other dimensions are often not thought of as part of traditional human factors and bring other disciplines such as industrial organizational psychology, organizational management, and operations engineering into the mix. Importantly, HSI is not simply the consideration of each of these dimensions in the context of a problem, but it involves understanding the problem from a systems perspective. This means that one cannot attend to a problem in one part of the system without also considering how changes will impact upon other systems' components. For instance, one should not design a display for sensor data without considering the ways those data will be used by the sensor operator, or without integrating the display with other displays used by the sensor operator, or without considering other dimensions such as training and selection that may be related.

1.2 Why HSI of RPAS?

The history of HSI in the context of RPAS is one of neglect (see Chapter 2). RPAS for military use were developed as experimental platforms without consideration of HSI and fielded early before HSI could be addressed even as an afterthought. Accident and mishap data for RPAS suggest that there are a number of shortcomings that have resulted from this neglect (Asim *et al.* 2010). The focus on the technology took a front seat to human concerns, even though there are many humans on the ground involved in their operation. But RPAS goes beyond human-machine or human-cockpit interaction. The other part of RPAS, which makes HSI essential is the nature of the system itself. There are multiple components of the system including the aircraft and the Ground Control System (GCS), themselves two large and complex systems. Interestingly, the focus on the technology has tended to be on the aircraft itself, rather than the GCS. This is paramount to focusing on a plane, but excluding the cockpit.

Further, as we consider questions such as sensor data exploitation or integration of RPAS into the NAS it becomes clear that additional components of the system need to be considered including sites dedicated to imagery analysis, other manned aircraft, air traffic control, and multiple remotely piloted aircraft systems. In addition, there is significant diversity in terms of RPAS platforms. It is a challenge to consider the implications that change in one part of a complex system has on other parts. The field of HSI has developed some approaches to