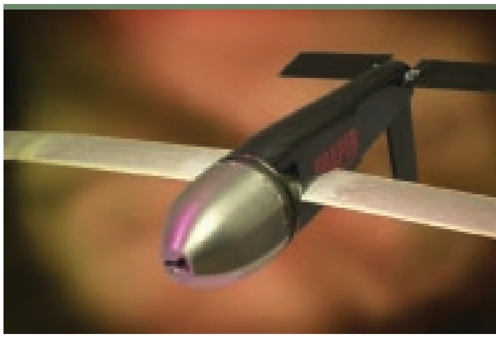
Patents



Draper Laboratory is renowned for its ability to integrate diverse technical capabilities into innovative and creative solutions for problems of national importance. Draper scientists and engineers are encouraged to advance the application of science and technology, expand the functions of existing technologies, and to create new ones.

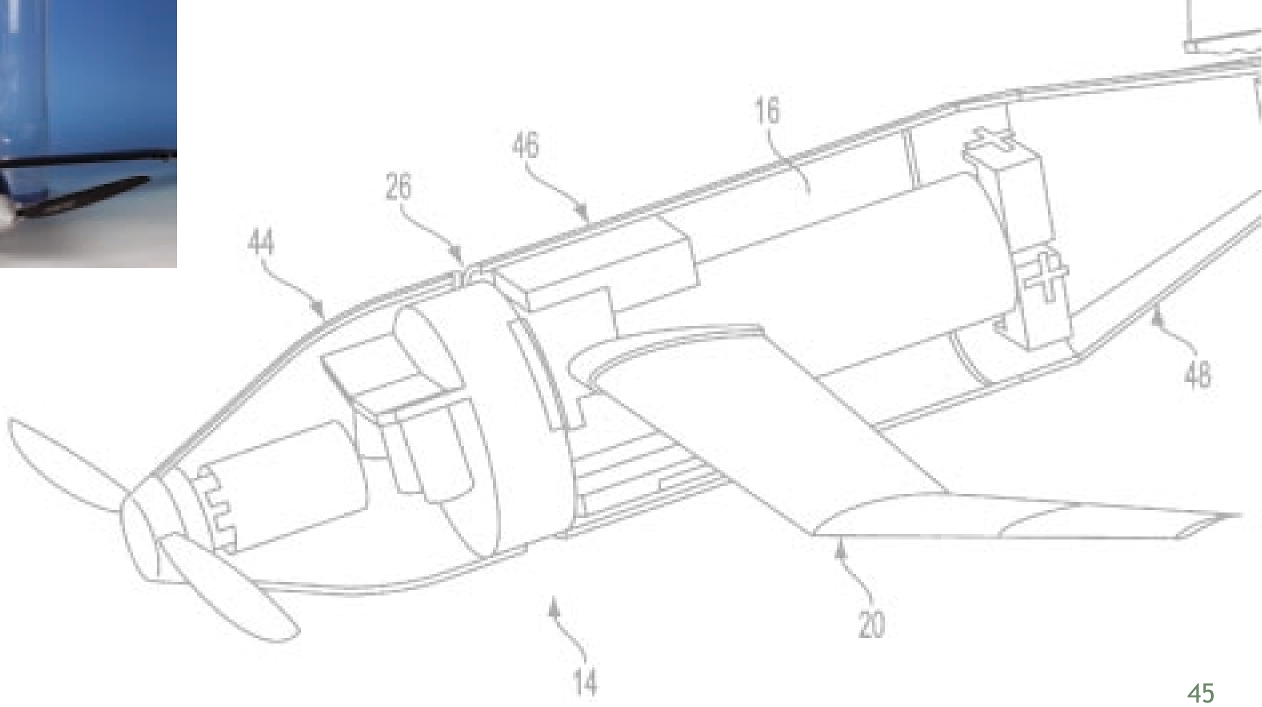
The disclosure of inventions is an important step in documenting these creative efforts and is required under Laboratory contracts (and by an agreement with Draper that all employees sign). Draper has an established patent policy and understands the value of patents in directing attention to effective individual accomplishments. Pursuing patent protection enables the Laboratory to pursue its strategic mission while recognizing its employees' valuable contributions to advancing the state-of-the-art in their technical areas. An issued patent is also recognition by a critical third party (the U.S. patent Office) of novel and creative work for which the inventor should be justly proud.

On average, Draper's Patent Committee typically recommends seeking patent protection for 50 percent of the disclosures received. Millions of U.S. patents have been issued since the first patent in 1836. Through December 31, 2002, 1143 Draper patent disclosures have been submitted to the Patent Committee since 1973; 584 of which were approved by Draper's Patent Committee for further patent action. As of December 31, a total of 424 patents have been granted for inventions made by Draper personnel. Nine patents were issued for calendar year 2002.

This year's featured patent is:

Flyer Assembly

The following pages contain an overview of the technology covered in the patent, followed by the official patent abstract issued by the U.S. Patent Office.



Flyer Assembly

Patent No. 6,392,213 B1 Issued May 21, 2002

Winner
of Draper's 2002 Best Patent Award

Richard T. Martorana, Jamie M. Anderson, Simon Mark Spearing, Seth Kessler, Brent D. Appleby, Edward V. Bergmann, Sean George, Steven Jacobson, Donald C. Fyler, Mark Drela, Gregory A. Kirkos, William W. McFarland, Jr.

This patent describes the design of a Flyer Assembly that can be packaged to be launched from an artillery gun, unfold and deploy itself, and loiter in-flight to perform surveillance activities. The concept was developed at Draper as the Wide Area Surveillance Projectile (WASP). First funded under an IR&D Draper/MIT partnership, it was then leveraged into a DARPA-funded project. This work involved many innovative engineering developments in materials; mechanical design and integration; aerodynamics; high-g survivability; guidance, navigation, and control; manufacturing; and field test. It is the type of complex first-of-a-kind system design at which Draper excels.

WASP is a folded Unmanned Air Vehicle (UAV) that is deployed as cargo from a standard 155-mm artillery round, the M-483A. A unique load-mitigation approach protects the Flyer from the extreme gun-fire environments, enabling it to use the gun's energy rather than its own to get to a time-critical target very quickly. WASP will use the existing 155-mm infrastructure for handling, loading, and transportation, and since it is expendable, it will not require a special UAV platoon for launch or recovery.

WASP's primary application is the identification of moving ground targets. In conflicts such as that recently fought in Kosovo, target identification was required to avoid civilian casualties. Similar imaging needs exist for battle damage assessment when it is prudent to use UAVs rather than put airmen at risk. Air wars such as Kosovo may become more common, where using ground forces is avoided, targets are too far inland for naval gunfire, and air spotters need images of ground target areas quickly. Forward air controllers must be close enough to see/sense and report ground information while at times putting themselves at risk. Any one of these situations justifies WASP deployment.

In a typical deployment sequence, WASP is fired to the area of interest at the projected target location. Post-apogee, the WASP assembly, enclosed in a protective steel "shroud," is expelled from the artillery shell as a standard cargo. The first stage of a ram air insertion device deploys to slow and de-spin the package. A second-stage parachute deploys to further slow and de-spin the assembly to a point where the wings can unfold safely. The shroud is jettisoned, WASP wings unfold, the parachute is jettisoned, and controlled flight begins when the electric propulsion motor is started.

WASP will be an autonomous vehicle. It will follow a mission plan that, in this application, would be prepared by personnel at a UAV Ground Control Station (GCS). It can be loaded at the gun or directly from the GCS while "on the fly" post-metamorphosis. WASP then executes the mission plan flying between individual targets or clusters of targets at about a 4,000-ft altitude with 1-ft imaging resolution. An onboard electro-optic imager sends images to the ground. The mission plan can be updated continuously. Video images can be sent directly to the Joint Standoff Target Attack Radar System (JSTARS), to ground operations centers, or directly to ground troops within the 80-km communication range. The sensor payload could also be a chemical/biological MEMS sensor currently being designed at Draper. WASP is congruent with the DARPA/Army Future Combat Systems development goal of multimission, rapidly deployed, light-logistics systems.

US006392213B1

(12) **United States Patent**
Martorana et al.

(10) **Patent No.:** **US 6,392,213 B1**
(45) **Date of Patent:** **May 21, 2002**

(54) **FLYER ASSEMBLY**

(75) Inventors: **Richard T. Martorana**, Andover; **Jamie Anderson**, Watertown; **Simon Mark Spearing**, Newton; **Seth Kessler**, Cambridge; **Brent Appleby**, Holliston; **Edward Bergmann**, Hopkinton; **Sean George**, Boston; **Steven Jacobson**, Shrewsbury; **Donald Fyler**, Needham; **Mark Drela**, Cambridge; **Gregory Kirkos**, Somerville; **William McFarland, Jr.**, Watertown, all of MA (US)

(73) Assignee: **The Charles Stark Draper Laboratory, Inc.**, Cambridge, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/690,000**

(22) Filed: **Oct. 12, 2000**

(51) **Int. Cl.**[7] **B64C 3/51**
(52) **U.S. Cl.** **244/3.1**; 244/3.24; 244/13; 244/49; 89/1.816
(58) **Field of Search** 244/3.1, 3.11, 244/3.15, 3.21, 3.24–3.3, 36, 49; 102/348, 501, 503, 380, 206; 89/1.809, 1.81, 1.815, 1.816, 1.819

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,695,555	A	*	10/1972	Chadwick	244/3.14
4,240,601	A	*	12/1980	Reed	244/160
4,296,894	A		10/1981	Schnabele et al.	244/3.27
4,410,151	A		10/1983	Hoppner et al.	244/63
4,752,052	A		6/1988	Galvin	244/3.29
5,456,427	A	*	10/1995	Greenhalgh	244/138 R
5,467,681	A	*	11/1995	Liberman	244/301
6,000,340	A	*	12/1999	Small	102/380
6,119,976	A	*	9/2000	Rogers	244/13
6,144,899	A	*	11/2000	Babb et al.	701/3
6,179,248	B1	*	1/2001	Putman et al.	244/36
6,260,797	B1	*	7/2001	Palmer	244/49

OTHER PUBLICATIONS

Carl Dietrich, On line Resume, Feb. 5, 1997 (WASP II Project summer 1998).*

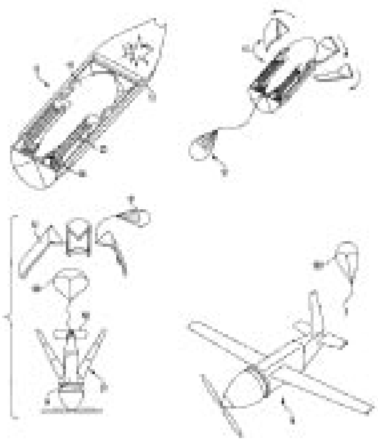
* cited by examiner

Primary Examiner—Galen L. Barefoot
(74) *Attorney, Agent, or Firm*—McDermott, Will & Emery

(57) **ABSTRACT**

A flyer assembly is adapted for launching with, transit in, and deployment from an artillery shell having a central void region extending along a ballistic shell axis. The flyer assembly includes a jettisonable shroud and a flyer. The shroud extends along a shroud axis, and is positionable within the central void region with the shroud axis substantially parallel to the shell axis. The flyer is adapted to withstand a launch acceleration force along a flyer axis when in a first state, and to effect aerodynamic flight when in a second state. When in the first state, the flyer is positionable within the shroud with the flyer axis parallel to the shroud axis and the shell axis. The flyer includes a body member disposed about the flyer axis, and a foldable wing assembly mounted to the body member. The wing assembly is configurable in a folded state characterized by a plurality of nested wing segments when the flyer is in the first state. The wing assembly is configurable in an unfolded state characterized by a substantially uninterrupted aerodynamic surface when the flyer is in the second state. The flyer assembly is adapted to be launched from a ballistic delivery system such as an artillery cannon, and can thus reach a target quickly, without expending system energy stored within the flyer. During launch, the flyer is coupled to the shroud so as to maintain a portion of the flyer in tension during an acceleration of the flyer along the flyer axis resulting from the launch. The flyer assembly is adapted to withstand the high g-load and high temperature environments of a cannon launch, and can tolerate a set-back g load of about 16,000 g.

29 Claims, 13 Drawing Sheets



(clockwise from bottom left) William W. McFarland, Jr., Edward V. Bergmann, Brent D. Appleby, Richard T. Martorana, Sean George, Donald C. Fyler, and Jamie M. Anderson. (not shown) Simon Mark Spearing, Seth Kessler, Steven Jacobson, Mark Drela, and Gregory A. Kirkos.

Richard T. Martorana

Richard T. Martorana is currently a Distinguished Member of the Technical Staff and the Technical Director for the WASP Program. With over 34 years of research, design, and development experience, he has directed and managed programs for NASA, USAF, DARPA, NAVSEA, and others. He was responsible for the thermal design of the Trident II IMU. His responsibilities have included: Section Chief for Fluid Mechanics and Thermal Engineering, Division Manager for Mechanical Design and Analysis, and Director of Systems Integration, Test, Evaluation, and Quality Management. He holds three U.S. patents in the areas of mechanical and thermal design. Mr. Martorana has BS and MS degrees in Mechanical Engineering from Columbia University and MIT, respectively, an MBA focused on management of innovation from Northeastern University, and he is a graduate of Harvard Business School's Program for Management Development.

Jamie M. Anderson

Jamie M. Anderson is a Principal Member of the Technical Staff and the Group Leader for Vehicle Systems in the Mechanical and Instruments Division and has been with Draper Laboratory since 1996. She served as the DARPA WASP program Mechanical Design Task Leader, during which the flight test vehicle was designed, fabricated, and tested. Dr. Anderson holds a BS in Mechanical Engineering from the University of California, San Diego (1989) and MS and PhD degrees in Oceanographic Engineering from MIT and the Woods Hole Oceanographic Institution (1992 and 1996, respectively).

Simon Mark Spearing (not shown)

Simon Mark Spearing has been an Associate Professor of Aeronautics and Astronautics at MIT since 1994. He worked as a research engineer at the University of California, Santa Barbara and subsequently at BP Research in Cleveland, OH. His research focuses on developing mechanism-based models and design approaches for advanced engineered materials, including composite materials for aerospace structures and MEMS. Educational activities focus on integrating the teaching of materials and structures in the undergraduate and graduate curricula. He is a participant in the educational and research activities of the Cambridge-MIT Institute (CMI) and the Singapore-MIT Alliance (SMA). He is an Associate Fellow of the AIAA and was chairman of that organization's Materials Technical Committee from 1997-1999. He is a member of the American Ceramic Society, Materials Research Society, American Society of Mechanical Engineers, American Society of Engineering Education, and the American Composites Society. He is deputy editor of Acta Materialia and J. Microelectromechanical Systems. Spearing has twice won the MIT Aero/Astro Department's award for outstanding teaching (1995 and 1997) and its award for student advising in 1999 and 2000. He has published over 120 papers in conference proceedings and journals and is listed as a co-inventor on five patents. Dr. Spearing received a PhD from the Cambridge University Engineering Department in 1990.

Seth Kessler (not shown)

Seth Kessler is the president of The Metis Design Corporation, a small design consulting firm specializing in the insertion of composite materials into nontraditional applications and nondestructive evaluation of composite materials. He had two internships with the Lockheed Martin Skunk Works as an advanced concepts and testing engineer on the X-33/VentureStar and JSF, and as a Draper Fellow, he worked on the WASP. In 1998, he received the Admiral Luis De Florez Award from MIT for Ingenuity and Creativity in Design; in 2001, he was awarded the American Society for Composites Research Scholarship; and in 2002, the Best Paper award for functional composites. He holds two patents, has authored over two dozen conference and journal publications in the fields of damage detection and durability in composite materials, and is a member and contributing author of the American Society for Composites, AIAA, and SPIE Smart Structures Society. Dr. Kessler received SB, SM, and PhD degrees in Aerospace Engineering from MIT.

Brent D. Appleby

Dr. Appleby is the Autonomous Control Group Leader. He has worked on numerous guidance, navigation, and control projects for a variety of applications, including autonomous rotorcraft, parafoils, undersea vehicles, guided projectiles, and a gun-launched UAV, as well as flexible space structures, satellites, and the Space Shuttle autopilot. He is also a Lecturer in the Aeronautics and Astro–nautics Department at MIT. Dr. Appleby received SB, SM, and PhD degrees from MIT.

Edward V. Bergman

Edward V. Bergmann is a Senior Systems Engineer in Draper's Systems Engineering Office. His main focus has been on missile defense. He is also contributing to the development of guided munitions and is working in the area of biomedical engineering. He was Technical Director for the navigation and communication upgrade to the A-10 aircraft, including GPS navigation and digital modem communication capabilities (1991-2000). As a Section Chief (1985-1991), he directed 17 engineers performing advanced development in adaptive control, spacecraft rendezvous and docking, ballistic missile guidance and control, hypersonic vehicle control, dynamic interaction of spacecraft control with flexible payloads, and submarine control. Mr. Bergmann also developed portions of the on-orbit autopilot currently used on the Space Shuttle. He has supervised several MIT Master's theses and was a member of several MIT doctoral committees. He is a member of the AIAA, Sigma Xi, and Tau Beta Pi. Mr. Bergmann has a BS in Aerospace Engineering and Astronomy from Boston University (1974), an MS in Aeronautics and Astronautics from MIT (1976), and has pursued doctoral studies in control theory and celestial mechanics at MIT (1976-1979).

Sean George

Sean George is a Senior Member Technical Staff in the Vehicle Systems Group. He has over four years experience working as an aerodynamicist on engineering projects related to the analysis, simulation, and design of a wide range of moving platforms, including projectiles, rotorcraft, ground vehicles, and airplanes. He has applied and validated a suite of computational fluid dynamics (CFD) tools suitable for the aerodynamic analysis of a general class of vehicles and projectiles, and was the Chief Configuration Design Engineer for the WASP vehicle, as well as several folded-flyer variants proposed for alternative missions. Mr. George analyzed and provided the configuration design for an IR&D-sponsored project that built a small, ducted rotorcraft. He provided analysis for several IR&D projectile projects used for guided munitions simulations, guidance algorithm development, and the design of a flare-launched optical sensor. He initiated and provided analytic support for a Draper-sponsored university research project to design a piezoelectric wing-warping actuator. He has also provided analysis for several preliminary system proposals, including an unmanned airdrop system, an inflatable, sampler retrieval system, and an ornithopter vehicle. Mr. George holds a BS in Applied Physics from Harvey Mudd College (1996) and an SM in Aeronautics and Astronautics from MIT (1998).

Steven Jacobson (not shown)

Steven Jacobson is currently a Group Leader in the Systems Engineering Group at the Avidyne Corporation. He is responsible for designing, building, testing, and certifying advanced glass displays for integrated flight decks. Previous positions at Draper include Group Leader, GPS/INS and Avionics Integration Group and the Integration and Test Task Lead for the WASP project through initial flight testing. He also served as both a test pilot and combat-ready fighter/attack pilot for the U.S. Air Force. Mr. Jacobson holds a BS in Astronautical Engineering from the U.S. Air Force Academy (1987) and an MS in Electrical Engineering from Northeastern University (1999).

Donald C. Fyler

Donald C. Fyler is a Senior Member Technical Staff in the Electro-Optic Sensors Group at Draper Laboratory. His 20+ years experience in the electromechanical engineering field includes 5 years experience in design, development, and analysis of electromagnetic and micromechanical components for precision instruments and 15 years experience in automated machinery design and analysis. He has a strong background in automatic machinery design, including mechanical design and analysis, electrical specification of machine controls, and machine control software. He specialized in flexible material assembly techniques for both apparel and composite fabrics. He holds a BS in Mechanical Engineering from the University of Massachusetts and an SM in Mechanical Engineering from MIT.

Mark Drela (not shown)

Mark Drela is the Terry J. Kohler Professor of Fluid Dynamics at the MIT Department of Aeronautics and Astronautics. He joined the faculty there in January 1986. His primary research interests are in low-speed and transonic aerodynamics and computational aerodynamic design methodology. He has developed a number of computational aerodynamic design/analysis codes that are currently used in the aircraft and gas turbine industry. He teaches aircraft design fundamentals, external aerodynamics, and fluid mechanics of boundary layers at the undergraduate and graduate levels. Prof. Drela participated extensively in the Chrysalis (1979), Monarch (1983-1984), and Daedalus (1985-1988) human-powered aircraft projects at MIT, and in the MIT Human-Powered Hydrofoil Project (1989-1993). His primary responsibilities in the Daedalus Project were detailed aerodynamic design, propulsion system design, and control system design and construction. Prof. Drela obtained SB, SM, and PhD degrees from MIT (1982, 1983, and 1985, respectively).

Gregory A. Kirkos (not shown)

Gregory A. Kirkos is currently a MEMS Design Engineer at Corning-Intellisense, where he designs MEMS devices for a host of application areas, including optical switching. He has 10 years of experience in mechanical design and analysis, with particular expertise in numerical methods (FEA/BEA) and hardware protoyping. He was formerly (1995-2000) a Mechanical Design Engineer/Mechanical Analyst in the Mechanical Design and Analysis Directorate at Draper. His work included mechanical design and advanced finite-element analysis toward the development of many of Draper's technologies, including MEMS tuning-fork gyroscopes, accelerometers, hydrophones, and chemical sensors. He also designed autonomous robotic systems as part of the Vorticity-Controlled Unmanned Undersea Vehicle (VCUUV) team, and was a Lead Mechanical Design Engineer of the WASP UAV system. He holds three U.S. patents. Mr. Kirkos received a BSME from Worcester Polytechnic Institute (1993).

William W. McFarland, Jr.

William W. McFarland, Jr. is a Member of the Technical Staff in the Vehicle Systems group in the Mechanical Design and Analysis Division. His responsibilities include the design and analysis of structures and mechanical subsystems for a range of applications, including mobile robotics, MEMS structures, inertial instruments, and strategic guidance systems. Mr. McFarland has an MS in Mechanical Engineering.