Design of Lightweight Engines for Unmanned Aerial Vehicles

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ABSTRACT

As manned aircraft missions become increasingly more expensive, new approaches are crucial to government agencies and industry. An alternative are unmanned aerial vehicles (UAVs), also referred to as drones. Today's UAVs perform missions requiring long endurance and low observability, some that could entail high risk. UAVs require lightweight, low-maintenance, and reliable propulsion systems to perform their missions. The U.S. Department of Defense (DoD) promotes the development of UAVs and related technologies through several of its agencies and programs. Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are among some of those options. Since 2009, a small company and a public university have been working on a 2010 STTR solicitation, selected for a Phase I contract in 2010 and invited for a Phase II effort on 2011.

1. INTRODUCTION

The concept of UAVs was first used in the American Civil War by means of balloons carrying explosive devices aimed at ammunition depots. Early in the 1900s, functional self-propelled aerial torpedoes were proposed and introduced as practical preemptive military assets. Later, in the 1960s, the U.S. military started to develop drones, built for spying and reconnaissance. After the Vietnam War, and furthermore following the first Gulf War, officials recognized the strategic importance of unmanned systems.

UAVs range from the size of an insect to that of a commercial airliner. The DoD currently possesses five UAVs in large numbers: the Air Force's Predator, Reaper, and Global Hawk; and the Army's Hunter and Shadow.

When combined with ground control stations and data links, UAVs form unmanned aerial systems (UAS). UAS comprise a rapidly growing portion of the U.S. military budget, and have been a long-term interest of U.S. Congress. Spending on UAS has increased from $284 million in FY2000 to $3.3 billion in FY2010.

2. SBIR/STTR PROGRAMS

SBIR programs fund early-stage Research and Development (R&D) projects of small companies; projects which serve a DoD need and have the potential for commercialization in the private sector and/or military markets. Companies apply first for a six to nine month Phase I award of $70,000 to $150,000, to test the scientific, technical and commercial merit, and feasibility of a particular concept. If a Phase I is successful, the company may be invited to apply for a two-year Phase II award of $500,000 to $1,000,000 to further develop the concept, usually to the prototype stage. Proposals are judged competitively on the basis of scientific, technical, and commercial merit.

STTR programs are similar in structure to SBIRs, but require cooperative R&D projects involving a small business and a research institution (i.e., universities, federally-funded R&D centers, or nonprofit research institutions). The purpose of an STTR is to create, for the first time, an effective channel for moving ideas from research institutions to the market, where they can benefit both private sector and military customers. A written agreement between the small business and the research institution, allocating "Intellectual Property" rights, is required for participating in this kind of program.

3. DESIGN, ANALYSIS, FABRICATION, AND TESTING COLLABORATION PROJECT

Since July of 2009, a small company and a public university have been working on a 2010 STTR solicitation: Navy Program/Proposal N10A–T001, titled: Advanced Materials for the Design of Lightweight JP5/JP8/DS2 Fueled Engines for Unmanned Aerial Vehicles (UAVs).

The proposal was awarded a Phase I contract on 2010 and invited to apply for a Phase II effort on 2011; first opportunity of its kind for both the company and the university.

The STTR solicitation cited the following objective:

"Develop a lightweight, efficient, and durable engine design capable of operating on JP5/JP8/DS2 fuels for use in unmanned aerial vehicles with a focus on advanced high strength to weight materials".

The Phase I effort included the development of a mockup prototype (developed using rapid-prototyping and 3D-printing techniques), the elaboration of comprehensive bi-monthly reports, and traveling three times to the NavAir facilities at Patuxent River, MD. During the first meeting with NavAir representatives, in August 5 of 2010, the company-university partnership was informed that there had been nearly 40 proposals submitted for the topic, that four were awarded Phase I contracts, and that the best two would be invited to receive a Phase II grant.

The company-university partnership Phase I effort was selected as the only finalist on March 17, 2011. The partnership was awarded a 3-month Phase I - Option 1, and invited to prepare a Phase II proposal. An additional Phase I - Option 2 was also granted to continue with proposals and refinement efforts.

A $500,000 Base Phase II grant to proceed with the development of a working prototype was submitted and accepted. After the acceptance of the proposal, several months passed before the final contract was approved by the DoDs contracts division. Work on the Base Phase II effort begun on August of 2012. The STTR Phase II program includes Phase II - Option 1, and Phase II - Option 2 extensions, each for $250,000, for further development or refinements.

As funding was received, purchases and/or agreements with additional suppliers and contractors were initiated.

4. Modeling and Validation

Throughout the Phase I effort of the project, baseline engine components were used to determine size and weight of critical elements of the proposed engine. Afterwards, by means of recognized analytical and comprehensive engineering methods, the proposed components were evaluated. Although the empirical predictions fulfilled or exceed required expectations, and proved that all the engine components will perform as anticipated, virtual modeling and Finite Element Analysis (FEA) techniques were used to ratify results.

Initial evaluations of the power-drive section of the engine designs confirm that the assembly (including pistons, connecting rods, crankshaft, and casing elements) are more than capable to withstand the predicted loads. Analysis results show that the stresses experienced by the deformable bodies of the assembly, will withstand loads six times larger than those anticipated. This could translate into further reductions of shape, thickness, and weight.

The most important aspect of the development of the engine cycle and configuration has been directed towards power-to-weight-ratio. The proposed configuration prototype will weigh around 12.5 pounds with an approximate output of 40 to 60 HP.

5. Future

Pending on lab-test results, by late 2013, a "platform" engine will be readied and delivered for field tests. If all objectives are fulfilled, the partnership could be eligible for Phase II.5 funding to continue with the project for an additional two years. If successful, the project could extend to a commercialization Phase III.

References

Gertler, J. (2012). "U.S. Unmanned Aerial Systems", *Congressional Research Service*, USA.

NOVA: Spies that Fly. (2002). Time Line of UAVs, http://www.pbs.org/wgbh/nova/spiesfly/uavs.html, 05/09/2013.

SBIR/STTR - Awards. (2010). Advanced Materials for the Design of Lightweight Engines for UAVs, http://www.sbir.gov/sbirsearch/detail/5969, 03/18/2013.

SITIS Archives - Topic Details. (2010). STTR N10A-T001 (Navy), http://www.dodsbir.net/sitis/archives_display_topic.asp?Bookmark=38281, 02/25/2010.

U.S. Department of Defense SBIR/STTR. (2010). Program Descriptions, http://www.acq.osd.mil/osbp/sbir/sb/program-descriptions.shtml, 08/04/2010.

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