04-130

AMENDMENT ONE

TO THE

MEMORANDUM OF AGREEMENT

BETWEEN

THE MINISTRY OF DEFENCE OF ISRAEL

AND

THE DEPARTMENT OF DEFENSE OF THE UNITED STATES OF AMERICA

FOR

A COOPERATIVE PROJECT OF RESEARCH IN THE FIELD OF

ROTORCRAFT AEROMECHANICS AND MAN-MACHINE INTEGRATION TECHNOLOGY

I hereby certify this to be a true copy of Amendment One to the Memorandum of Agreement Between the Ministry of Defence of Israel and the Department of Defense of the United States of America for A Cooperative Project of Research in the Field of Rotorcraft Aeromechanics and Man-Machine Integration Technology. The Office of the Deputy Assistant Secretary of the Army for Defense Exports and Cooperation, Armaments Cooperation Division maintains custody of a signed copy of the Agreement.

Stephen D. Connors

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1. INTRODUCTION

The Ministry of Defence of Israel and the Department of Defense of the United States of America, hereinafter referred to as the "Parties", entered into a Memorandum of Agreement (MOA) on 2 December 1992 on Rotorcraft Aeromechanics and Man-Machine Integration Technology.

2. AMENDMENT AND EXTENSION

2.1 In accordance with Article XVIII (AMENDMENT, TERMINATION, ENTRY INTO FORCE AND DURATION) of the Rotorcraft Aeromechanics and Man-Machine Integration Technology MOA, the Parties hereby mutually agree to extend the Rotorcraft Aeromechanics and Man-Machine Integration Technology MOA to 2 December 2010 by amending the MOA as follows:

2.1.1 Replace the current MOA Article IV (PROJECT ORGANIZATION AND MANAGEMENT), Paragraph 2, with the following, "The Director of Defence R&D and the Associate Director for Aviation Technology, U.S. Army Aviation and Missile Command are authorized, when necessary and only within the scope of this Agreement (Article III.2), to revise the individual task statements contained in Annexes A and B to reflect changes made in the technical approaches. Such changes shall be reported through appropriate national channels. These changes shall be by mutual Agreement.".

2.1.2 Replace the current MOA Article IV (PROJECT ORGANIZATION AND MANAGEMENT), Paragraph 4.a. For the United States: with "Associate Director for Aviation Technology, U.S. Army AMCOM, ATTN: AMSAM-RD, Building 5400, Redstone Arsenal, AL 35898-5000"

2.1.3 Change Article XVIII (AMENDMENT, TERMINATION, ENTRY INTO FORCE AND DURATION), Paragraph 1, from "The text of this Agreement and Annex A may be amended by the written consent of the Parties." to "The text of this Agreement may be amended by the written consent of the Parties. "

2.1.4 Change Article XVIII (AMENDMENT, TERMINATION, ENTRY INTO FORCE AND DURATION), Paragraph 6, First sentence to "This Agreement consists of 18 Articles and 2 Annexes, and shall be entered into force upon signature by both Parties and shall remain in force for 18 years unless terminated by either Party."

2.1.4 Add Annex B, as attached hereto.

2.1.5 Throughout the Agreement replace "Annex A" with "Annexes A and B".

2.2 All other provisions of the Rotorcraft Aeromechanics and Man-Machine Integration Technology MOA remain unchanged.

3. EFFECTIVE DATE

This AMENDMENT ONE shall enter into force on the date of the last signature below with an effective date of 1 December 2001.

4. SIGNATURES

The undersigned being duly authorized have signed this AMENDMENT ONE to the Rotorcraft Aeromechanics and Man-Machine Integration Technology MOA in two (2) copies, both in English.

For the Ministry of Defence of Israel	For the Department of Defense of the United States of America
S. Keren	[signature]
Name	Name
Brig. Gen. (Ret.) Shmuel Keren **Director of DDRD** **I.M.O.D**	Craig D. Hunter Deputy Assistant Secretary of the Army for Defense Exports and Cooperation
Title	Title
28 Aug. 2003	23 June 2003
Date	Date
TEL-AVIV	Arlington, Virginia
Place	Place

ANNEX B

The purpose of this MOA is to perform cooperative research in the various subdisciplines of rotorcraft aeromechanics and man-machine integration technology; specifically to develop analytical techniques, to improve experimental capabilities and to generate experimental data bases. The technology disciplines are as follows:

Man-machine interface. This refers to the interaction between the aeromechanics characteristics of the rotorcraft and the human operator characteristics of the pilot, to the extent that the interaction affects the overall system performance and pilot workload. Scope includes mathematical modeling, display system design, ground-base and in-flight simulation, and simulator development.

Flight Mechanics and control. This refers to the mathematical description and analysis of the motion and control of rotorcraft in flight. Design and analysis of control laws for manned and unmanned rotorcraft are included in this technical area. Scope includes analytical and numerical modeling of aerodynamics phenomena, analysis of wind tunnel and flight data, system identification, and development and simulation evaluation of control system concepts.

Unsteady flow simulation and control. This refers to the study of the physics of unsteady flow around an oscillating rotorcraft blade and evaluating concepts for mitigating the effects of blade stall due to unsteady flow. Scope includes collecting experimental wind tunnel and flight test data, and analysis using large-eddy-simulation computational techniques.

Within the three rotorcraft technology disciplines, five tasks have been identified for collaboration in the first thirty-six months of Amendment (ONE). Each of these tasks involves technology of future or emerging systems. Each Party already has an active research program in each area, and there is a balance in facilities and capabilities. A coordinated approach to work in each task has been devised and is described in the following Statement of Work.

Statement of Work for Amendment (ONE) to the U.S./Israel Memorandum of Agreement on Rotorcraft Aeromechanics and Man-Machine Integration Technology

Four tasks have been identified for collaboration to start immediately and continue for the first thirty-six months of the Amendment (ONE). A fifth task is included in the nine-year extension, but will not be initiated immediately. The background, objectives and scope of the proposed research work in each task is described below:

<u>Task 1 – Alleviating the Effects of Blade Stall Using Unsteady Flow Control</u>

Background. Aerospace vehicles of the future will be required to perform at much higher load conditions, and much wider ranges of attack than present systems. Therefore, there is an increasing need for aerodynamic flow control, and a search for new concepts and techniques. Experiments using oscillatory blowing flow control (OBFC) on fixed and oscillating wings have shown very high lift at very low values of drag during use in steady flow conditions in the laboratory, and for suppression of separation on helicopter rotor blade airfoils. Researchers at the Tel Aviv University have conducted extensive wind tunnel studies of the effects of unsteady flow injections on generic airfoils at subsonic conditions and have begun computational analysis. Researchers at the Army Aeroflightdynamics Directorate have conducted limited unsteady flow control tests on oscillator airfoils in compressible flow conditions more representative of rotor blades. They have also conducted extensive analytical studies using Large-Eddy simulation techniques. Under the Amendment (ONE) task, research will compare wind tunnel data, test techniques, and modeling methods as it relates to the alleviation of blade stall using unsteady flow control methods.

Objectives. The objectives of this research task are to:

- Study fluid physics of unsteady flow control
- Extend the existing wind tunnel data base for unsteady flow control (TAU, IIT, AFDD)
- Investigate the use of Large Eddy Simulation code for correlation with experiment.

Scope. Wind tunnel tests of fixed and oscillating airfoils are conducted to study the benefits and limitations of unsteady flow control techniques to mitigate the effects of blade stall. Tests will evaluate the benefits and drawbacks of alternative methods of flow actuation. Computation methods based on CFD and Large-Eddy simulation will be developed and validated against the experimental database for use in predicting optimized flow control configurations. Task may include flight test evaluation of promising flow control concepts.

Task 2 – Application of Optimization Techniques to Preliminary Design Tradeoff Studies

Background. Optimization techniques can be used to help reduce the labor necessary in using current analysis tools to find the "best design". Optimization techniques enable the systematic evaluation of various combinations of design variables to minimize a "cost function" subject to design constraints. The cost function can represent a single parameter such as cost, weight, power, or some combination of parameters. In the event an acceptable design cannot be found, the optimization process will indicate which constraint is limiting the design. Optimization techniques are more practical today since the availability of sufficient computer resources are available for modest cost. There has been extensive work done at the Technion-Israel Institute of Technology and U.S. Army Aeroflightdynamics Directorate on developing design optimization procedures. This task involves the application of these techniques to specific preliminary design tradeoff studies.

Objectives: The objectives of this research task are:

- Optimization methods that permit the determination of rotor lift distribution of edge-wise lifting rotors for minimum induced power as a function of flight condition
- Study the benefits and limitations of competitive UAV design concepts based on range/fuel considerations
- Study the maximum maneuver flight envelope boundaries and trim states as a function of preliminary design configuration choices.
- Develop design rules and constraints for optimizing rotorcraft configurations in an automated design environment.

Scope. Research and develop generic optimization controllers suitable for use with in house analysis tools and to apply it to important PD problems. The controller will be constructed in such a way that a designer can easily set up the optimization problem. The Task researcher will create optimization algorithms that can take the cost function, optimization parameters and design constraints and perform a systematic evaluation or various combinations of independent design parameters to minimize the cost function. Case studies will be conducted to address specific problems in the rotorcraft manned and unmanned preliminary design field.

Task 3- Stabilization of Rotorcraft Sling-Load Systems

Background. Many loads of interest develop significant aerodynamics such that operational speeds are limited by load stability well below the power limited speed of the helicopter alone. Analytical methods for predicting stability are inadequate, and reliance is placed on expensive wind tunnel and flight test evaluations.

Twin and multilift systems use 2 or more helicopters to carry heavy loads. Twin lift has been proposed periodically since the early 60's as an alternate to the development of heavier lift helicopters and to carry loads in excess of the available single lift capacity. The main obstacle to an operational capability has been coordination of helicopters to maintain equal loading during maneuvering flight. This was seen in a 1960's flight test to be just beyond the capacity of unaided pilots to accomplish.

Researchers at the Army/NASA Rotorcraft Division and the Israel Ministry of Defense have ongoing research programs on load aerodynamics and instrumentation, single and twin lift dynamic models, and load stabilization and control. Under the MOA slung load task, researchers will work cooperatively to measure and model load aerodynamics, study and test passive and active load stabilization, and develop and demonstrate twin lift control in a realistic simulation.

Objectives:

- Develop realistic simulation models of load aerodynamics.
- Conduct simulation studies of passive and active load stabilization techniques and test.
- Implement realistic twin lift simulation models, including a real time simulation.
- Develop twin lift control algorithms and demonstrate in simulations.

Scope. Load aerodynamics are studied via instrumented load flight tests, and CFD and wind tunnel data. The principal test load will be the 6x6x8 ft CONEX cargo container used in previous wind tunnel and flight test activities and limited in operations to 60kts. Configuration optimization and load passive and active stabilization are studied in a validated simulation model of the UH60 and slung load, and demonstrated in flight for feasible configurations. Real time and non-real time twin lift simulation models are implemented. Control logic with various degrees of automation and instrumentation requirements are developed and promising schemes evaluated in appropriate simulations.

Task 4 - Innovative Guidance and Control Technologies for Rotorcraft UAVs (RUAVs)

Background: Rotorcraft UAVs provide a unique capability for accomplishing difficult and dangerous military and civil missions without risking pilots or high-cost manned aircraft. However, the current state-of-art in guidance, dynamics, and control technologies for RUAVs is sufficiently less than what is needed for fully operational system. Under this Task, researchers will conduct basic studies on the simulation and control of a generic RUAV.

Objectives:

- Simulate models representative of RUAV configuration and missions
- Develop waypoint guidance and landing simulation techniques
- Evaluate requirements for inner loop control laws for degraded weather ops
- Develop autonomous guidance for mod-course flight path deviation
- Simulation (and flight test) validation of UAV guidance and control concepts

Scope. A rotorcraft UAV configuration will be simulated using analytical models. This effort will include the simulation and validation of airframe and rotor characteristics as well as guidance, navigation, and ground station interfaces. Control laws for inner loop stabilization at hover and forward flight will be developed and validated in simulation and flight. Algorithms will be developed for waypoint navigation and moving map displays. Algorithms for waypoint control and autonomous guidance will be studies and validated in simulation and flight test.

Task 5 - Design and Evaluation of Symbology to Improve Pilot Performance

Background. According to recent surveys, approximately 26% of all helicopter accidents involve in-flight collisions with terrain. Most of these accidents are associated with flight modes unique to helicopters, such as low-altitude precision maneuvers and hovers. In addition, they tend to occur in degraded visual environments, such as whiteout or brownout conditions, or during nighttime operations when the pilot is using night vision goggles or FLIR imagery. From a human factors perspective, these accidents reflect either incorrect or insufficient spatial situation awareness (SSA). Maintaining SSA involves a variety of cognitive processes. A second factor impacting SSA is the high workload associated with precision low altitude operations. In degraded visual environments, the extraction and processing of the appropriate visual information is itself demanding. For their part, standard attitude, altitude, and airspeed indicators provide unintegrated information that requires mental computations and/or mental transformations before they can support a real-time spatial model. In the absence of a stability augmentation system, inner-loop control of the aircraft takes effort. Even in ideal visual conditions, these processing demands may combine to overload the pilot, causing him or her to lose SSA. This Task proposes to design and evaluate helmet-mounted display (HMD) symbology to support SSA, and to test the effects on pilot performance in the low-altitude, low-visibility flight environment. The goal is to demonstrate enough performance improvement that, if the results were extrapolated to the real world, in-flight collisions with terrain would be reduced significantly.

Objectives:

- Design and evaluate candidate helmet-mounted display (HMD) symbology sets to support SA in a degraded visual environment.
- Demonstrate technology for reducing occurrences of in-flight collisions with terrain

Scope. The Task will examine how well pilots perform a series of low altitude precision maneuvers (primarily hover) in low visibility. Performance will be assessed under various levels of control difficulty. The experiment just described is expected to be only the first in a series of evaluations, additional forms of HMD symbology will be developed and tested. The best design will be tested in a higher-fidelity simulation environment and eventually in flight test. A parallel effort is anticipated that will integrate advanced HMD designs into an advanced cockpit containing both Head-up and Panel-mounted displays, together with some form of active alerting system.