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Missile Flight Simulation **An Ada Object Oriented Missile Flight Simulation** **EQUATIONS OF MOTION FOR FLIGHT SIMULATION OF THE ASROC MISSILE. Weapons Performance Division** Missile Dynamics Equations for Guidance and Control Modeling and Analysis **Developing CMMCA Flight Profiles for Cruise Missile Tracking** **Survey of Missile Simulation and Flight Mechanics Facilities in NATO** **Mini-Rocket User Guide** An Inexpensive Real-Time Interactive Three-Dimensional Flight Simulation System **Fundamentals of Six Degrees of Freedom Aero Sim and Analysis in C++** **Cooperative Guidance & Control of Missiles Autonomous Formation** **Final Report of the Flight Mechanics Panel Working Group WG-12 on Validation of Missile System Simulation** Pershing II Simulation Studies **Project DAME - Tactical Instrumented Missile Simulation Testing** **Survey of Missile Simulation and Flight Mechanics Facilities in NATO.** *Optimal External Configuration Design of Missiles* Ground Based Intercept of a Ballistic Missile: Simulation Truth/Model Interface **Modeling and Simulation of Aerospace Vehicle Dynamics** *A Digital Program for the Simulation of Missile Dynamics in Pitch During the First Few Minutes of Flight* **Descent Guidance and Control for Tactical Guided Weapons with Emphasis on Simulation and Testing** *An Air to Surface Missile Simulation Using a Digital Simulation Language* *FMP (Flight Mechanics Panel) Working Group WG-12 on Validation of Missile System Simulation* **Automatic**

Control of Aircraft and Missiles *AIAA Flight Simulation Technologies Conference* **Falcon Air Combat Interactive, Networked, Moving Platform Simulators** A Fuzzy Logic Optimal Control Law Solution to the CMMCA Tracking Problem *An Innovative Approach to Missile System Design* Test and Evaluation of the Tactical Missile **Post Flight Digital Simulation of the Atlas 40-D Missile Analysis and Compilation of Missile Aerodynamic Data** Missile Guidance and Pursuit **Validation of Missile Simulation** Practical Design of Flight Control Systems for Launch Vehicles and Missiles **Theory, Methodology, Tools and Applications for Modeling and Simulation of Complex Systems Strategic Forces Analysis and Compilation of Missile Aerodynamic Data** Use of Hardware-in-the-Loop Simulation (HWIL) in the Development, Test, and Evaluation of Multi-Spectral Missile Systems *An Optical Display Unit for Wide Angle Simulation of the Flight of the Malkara Missile*

Previous research has produced a real time FOG-M missile flight simulation using defense Mapping Agency digital terrain elevation data and a Silicon Graphics, Inc. IRIS 3120 graphics workstation. This study is a continuation of that project with the goals of providing more realistic targets and allowing viewing the terrain from inside several different types of vehicles. In addition, the use of Ethernet network communications between two workstations taking part in the simulation is used to create a missile/target gaming environment. Keywords: Fiber optic guidance. Results of a previous program -- an instrumented modified 14-inch bomb dummy unit (BDU) flown on an F-111 aircraft --

were applied, analytically, to an AIM-7E (Sparrow) motor. An inert Sparrow motor was instrumented with accelerometers, strain and stress gages, and thermocouples. It was then subjected to thermal, dynamic, and captive-flight simulation tests that cover the expected range of loadings to be encountered in captive flight on high-performance aircraft. Random vibration input control was based on BDU response during actual captive flight, which compared favorably with MIL-STD-810C requirements at frequencies below 400 Hertz. An enhanced spectral input based on assumed response on aircraft such as an F-4 was also run. Both analysis and experiment indicate that stresses imposed on the motor from thermal changes are relatively low. Propellant characterization and aging data and gage calibration data are presented. Calibration data presented are sufficient to permit data reduction from actual captive-flight tests. The U.S. Army Aviation and Missile Command (AMCOM) Advanced Simulation Center (ASC) provides hardware-in-the-loop (HWIL) simulation support to Program Executive Officers (PEO) and Project Managers (PM) who are responsible for developing and fielding precision guided missiles and sub-munitions for the U.S. Army. The ASC is also engaged in cooperative HWIL simulation tasks supporting other Armed Service Agencies, NATO and other U.S. allies. HWIL simulation provides a means of exercising missile guidance and control hardware in simulated flight, wherein the missile sensors are stimulated with input signals which make the system behave as though it were in actual operation. Real-time computers are used to control the target and countermeasure signatures and battlefield scenarios. Missile flight dynamics, responding to the commands issued by the guidance and control system hardware/software, are simulated in real-time to determine the missile trajectory and to calculate target intercept conditions. The ASC consists of 12 HWIL simulation facilities developed over a period of 20 years. These facilities contain special purpose infrared and RF signal generation equipment, flight motion simulators, radiation chambers, optics, and computers. They provide in-band target signatures, countermeasures, and background scenarios in the microwave, millimeter wave, infrared and visible regions of the electromagnetic spectrum. The ASC HWIL simulation facilities are an important source of test and evaluation data and have a critical role in all phases of a missile system life cycle. The development of a new generation of missile systems that use multi-spectral seekers has imposed unique and difficult requirements on ASC HWIL simulation facilities. For the past three years, the U.S. Army Aviation and Missile Command (AMCOM) has been developing a HWIL simulation facility to test common aperture multi-spectral missile seekers. This report presents the results of a Flight Mechanics Panel (FMP) sponsored survey of twenty-four (24) simulation and flight mechanics facilities in six NATO community nations: France, the Federal Republic of Germany, Italy, the Netherlands, the United Kingdom and the United States. The survey included government and contractor facilities and was obtained by a combination of a questionnaire mailed to each facility and a follow-up on-site visit and interview with facility managers and operational personnel. This document describes the use of a missile/rocket fly-out model that represents a significant advance in efficiency for these type of simulations given its modest requirements for complexity and runtime efficiency. The model is useful for generating trajectories and associated flight parameters for multi-stage powered missiles flying over a rotating, spherical earth. The model uses a unique osculating plane formulation that preserves relatively high fidelity while maintaining run-time efficiency and simplicity of input. This formulation provides for user-specified flight guidance options including ballistic flight and profiles for acceleration, flight path angle rate, and flight path angle. This model was designed to expedite many of the same analyses conducted with the old industry-standard ROCKET code -- hence the name Mini-Rocket. While this manual documents the use of a standalone, executable version of Mini-Rocket, it also provides enough information to configure the Mini-Rocket source code as an embedded model and/or to modify it for a specific application. Mini-Rocket was built with C++ Model Developer (CMD). CMD is a highly-refined C++ source code environment for building missile simulations such as this one. CMD provides a common platform for building a wide range of missile simulations ranging from simple fly-out models to high-fidelity six Degree-of-Freedom (DOF) simulations. The benefit is a clearly structured architecture that makes it easy to maintain and discern model source code. However, no C++ knowledge is needed to use Mini-Rocket. Equations of motion are presented for a three dimensional trajectory simulation under the assumption that, during the thrust phase, the configuration is a rigid body and has 90 degree rotational symmetry. For flight simulation during the after-burning phase equations based on particle ballistic theory are presented. The instantaneous position of the missile in space is defined relative to a spherical, rotating earth. Aerodynamic coefficients considered during the thrust phase are functions of Mach number, angle of attack and effective roll angle. During the after-burning phase the aerodynamic drag coefficient is a function of Mach number. The formulation was designed for the specific purpose of generating accurate fire control data for the ASROC missile but may have wide application among other types of rockets. For this reason certain terms have been included in the model which are not significant for the ASROC application. Among them are terms to simulate effects of a rotating earth. As an option the free-flight after-burning phase may be simulated by a six-degree-of-freedom model. This four-volume set (CCIS 643, 644, 645, 646) constitutes the refereed proceedings of the 16th Asia Simulation Conference and the First Autumn Simulation Multi-Conference, AsiaSim / SCS AutumnSim 2016, held in Beijing, China, in October 2016. The 265 revised full papers presented were carefully reviewed and selected from 651 submissions. The papers in this second volume of the set are organized in topical sections on HMI and robot simulations; modeling and simulation for intelligent manufacturing; military simulation; visualization and virtual reality. The Air Force has recently acquired two aircraft dedicated for cruise missile tracking. These aircraft, known as the

Cruise Missile Mission Control Aircraft (CMMCA), are responsible for collecting data from the missile and United States. Due to tracking and positively controlling the missile during live fire testing over the western the limited tracking radar range and the flight characteristics of the CMMCA, tracking cruise missiles through complex maneuvers is not always possible. A FORTRAN optimization, based on flight simulation and optimal control theory, was written in a prior thesis effort in order to determine optimal CMMCA flight profiles for tracking cruise missiles through certain maneuvers. The primary emphasis of this research effort was to conduct an analysis of the previously written optimization program, and to make the appropriate modifications to improve the performance and efficiency of the program. The program was tested over several different missile flight paths, using a variety of different initial program conditions and input parameters, in order to find the program modifications and parameter settings that produced the best CMMCA flight profiles in response to the given cruise missile flight path. Radar tracking, Control theory, Guided missiles, Flight simulation, Computerized simulation, Guidance. A textbook for an advanced undergraduate course in which Zipfel (aerospace engineering, U. of Florida) introduces the fundamentals of an approach to, or step in, design that has become a field in and of itself. The first part assumes an introductory course in dynamics, and the second some specialized knowledge in subsystem technologies. Practicing engineers in the aerospace industry, he suggests, should be able to cover the material without a tutor. Rather than include a disk, he has made supplementary material available on the Internet. Annotation copyrighted by Book News, Inc., Portland, OR The report contains the results of the post flight digital simulation of the Atlas XSM-65-40D missile. The missile was flight tested previously and the study was made by simulating the flight of the 40-D missile on the IBM 704 computer. (Author). A prototype flight simulator for the Fiber-Optically Guided Missile (FOG-M) is presented. This prototype demonstrates the practicability and feasibility of using low-cost graphics hardware to produce acceptable simulation of flight over terrain generated from Defense Mapping Agency (DMA) digital elevation data. The flight simulator displays a dynamic, three-dimensional, out-the-window view fo the terrain in real-time while responding to operator control inputs. The total system cost (software and hardware) of the simulator is an order of magnitude less than most flight simulation systems in current use. A missile flight simulation is a computational tool that calculates the flight of a missile from launch until it engages the target. The simulation is based on mathematical models of the missile, target and environment. This book provides instruction for the preparation of these mathematical models to simulate the flight of a surface-to-air missile. The 2nd Edition of Missile Flight Simulation provides updated simulation processes using MATLAB(R) and Simulink(TM), while improving and clarifying previous content. The book may be used as a reference or as a textbook, although it is devoid of exercises. However, the reader is encouraged to perform the simulation of

Charter 12 using MATLAB(R) and Simulink(TM), or a programming language such as FORTRAN (see Chapter 10). The book is not intended to be a missile flight engineering reference and does not contain every aspect of missile flight. It provides the appropriate content for simulating missile flight from launch to terminus only. This investigation encompassed a study of the integration and operation of the Satellite Tool Kit and Missile Flight Tool modules. The Satellite Tool Kit display and Missile Flight Tool truth data designed in this investigation are components of a ballistic missile defense simulation, and are required to visualize and begin the simulation. Further, the integration and visualization of several of the ballistic missile intercept system components was explored. The continuing evolving capability of guided weapons demands ever more knowledge of their development. This modern and comprehensive book covers the control aspect of guidance of missiles, torpedoes, robots, and even animal predators, from the viewpoint of the pursuer. The text studies trajectories, zones of interception, the required manoeuvre effort, time of flight, launch envelopes, and stability of the guidance process. Mathematics at first-year university level is the only prerequisite. Acquaintance with feedback control theory would be helpful to the reader. Covers the control aspect of guidance of missiles, torpedoes, robots, and even animal predators, from the viewpoint of the pursuer Studies trajectories, zones of interception, the required manoeuvre effort, time of flight, launch envelopes, and stability of the guidance process One of the key findings of

AGARDograph No. 279 'Survey of Missile Simulation and Flight Mechanics in NATO' was that very little effort was expended in missile simulation validation. No standard or well-defined techniques were in use adequate to communicate confidence in missile simulations to persons not directly involved in the process of simulation development. Therefore the AGARD FMP formed Working Group 12 to examine missile simulation validation and confidence building techniques. The group recommended a simulation terminology that should simplify the validated process. (JES). Captain Pete "Boomer" Bonanni flew F-16 Fighter planes and is now bringing his inside tactics to the Falcon flight simulator. This teaches the basics of how to fly and fight, yet more advanced users desiring to learn real tactics from a pro will also want this book. This report provides a general analysis of the flight dynamics of several surface-to-air and two air-to-air missile configurations. The analysis involves three phases: vertical climb, straight and level flight, and constant altitude turn. Wind tunnel aerodynamic data and full scale missile characteristics are used when available; unkonwn data are estimated. For the constant altitude turn phase, a three degree of freedom flight simulation is used. Important parameters considered in this analysis are the vehicle weight, Mach number, heading angle, thrust level, sideslip angle, g loading, and time to make the turn. The actual flight path during the turn is also determined. Results are presented in graphical form. This Second Edition continues the fine tradition of its predecessor by exploring the various automatic control systems in aircraft and on board missiles. Considerably expanded and updated, it now includes new or additional material on: the effectiveness of beta-beta feedback as a method of obtaining coordination during turns using the F-15 as the aircraft model; the root locus analysis of a generic acceleration autopilot used in many air-to-air and surface-to-air guided missiles; the guidance systems of the AIM-9L Sidewinder as well as bank-to-turn missiles; various types of guidance, including proportional navigation and line-of-sight and lead-angle command guidance; the coupling of the output of a director fire control system into the autopilot; the analysis of multivariable control systems; and methods for modeling the human pilot, plus the integration of the human pilot into an aircraft flight control system. Also features many new additions to the appendices. The Air Force uses the C-18 Cruise Missile Mission Control Aircraft (CMMCA) to radar track cruise missiles (CM) during test flights. Because of the complexity of the CM flight profiles, maintaining radar coverage at all times is very difficult. This thesis attempted to apply optimal control theory to construct a simulation providing 100% radar coverage. The simulation was divided into ten second intervals, and fuzzy logic was used at the start of each interval to determine the set point, i.e., that point in space where the CMMCA should be in ten seconds. The set point calculation's fuzzy logic balanced CMMCA maneuvering based on present and future CM positions. Three different future times were used: 60, 90 and 120 seconds ahead, and the performance for each time was compared. The simulation was performed on an IBM compatible PC with Matlab and Simulink (both by The MathWorks). The final form of the fuzzy logic provided varying radar coverage at each look ahead time for a complex CM flight path (CM in 20 degrees of bank) 1850 seconds long. At 120 seconds look ahead time, the coverage was 100%. When the same profile was performed with the CM in 30 degrees of bank, coverage was degraded, and 60 seconds look ahead performed best ... CMMCA, Cruise Missile Tracking, Fuzzy Logic, Optimal Control, Flight Simulation, Computer Simulation, Guidance. The main area of emphasis in the work is to investigate the methods and technology for aerodynamic configuration sizing of missiles and to develop a software platform (EXCON) in MATLAB environment as a design tool which has an ability of optimizing the external configuration of missiles for a set of flight requirements. In this multidisciplinary optimization (MDO) process, the external geometry candidates are graded according to their flight performances to discover an optimum solution. All of the flight performance data are obtained by running a flight simulation which uses Missile DATCOM as the aerodynamic coefficient prediction software package. In order to solve the resulting multi-objective optimization problem with a set of constraint of linear and nonlinear nature, improved evolutionary methods are applied. Also, a case study, the reconfiguration problem of an anti-ship cruise missile, is presented to demonstrate the accuracy and feasibility of the conceptual design tool developed. The book is suitable for engineers who are involved in the system-level preliminary design of the cruise missiles or in rapid prototyping of aircrafts using advanced MDO techniques. This report provides a general analysis of the flight dynamics of several surface-to-air and two air-to-air missile configurations. The analysis involves three phases: vertical climb, straight and level flight, and constant altitude turn. Wind tunnel aerodynamic data and full scale missile characteristics are used when available; unkonwn data are estimated. For the constant altitude turn phase, a three degree of freedom flight simulation is used. Important parameters considered in this analysis are the vehicle weight, Mach number, heading angle, thrust level, sideslip angle, g loading, and time to make the turn. The actual flight path during the turn is also determined. Results are presented in graphical form. This book primarily illustrates the rationale, design and technical realization/verification for the cooperative guidance and control systems (CGCSs) of missile autonomous formation (MAF). From the seven functions to the five major compositions of CGCS, the book systematically explains the theory and modeling, analysis, synthesis and design of CGCSs for MAF, including bionics-based theories. Further, the book addresses how to create corresponding digital simulation analysis systems, as well as hardware in the loop (HIL) simulation test systems and flight test systems, to evaluate the combat effectiveness of MAF. Lastly, it provides detailed information on digital simulation analysis for a large range of wind tunnel test data, as well as test results of HIL system simulations and embedded systems testing. A six degree of freedom air to ground missile simulation is developed utilizing a digital simulation language. The simulation incorporates all aerodynamic coefficients and missile characteristics to completely describe missile performance over various flight regimes. Development of the simulation is done in modular form wherever possible to increase the flexibility and to cause a more general simulation. A typical flight regime is given using data for a particular missile and the results indicated a miss distance of 7 feet from a launch position of nearly 30 miles away. All miss distances appear to be less than the Circular Error Probable for the missile in the cases attempted. The digital simulation language used in the simulation affords an efficient and simplified method for the dynamic modeling of a complex missile system. The program could be extended to other systems both air to air and ground to air without undue difficulty. (Author). This book gives in a concise and easy to understand form the various aspects of Practical Design of Flight Control Systems for Launch Vehicles and Missiles. It covers almost every aspect of Flight Control System Design which a designer would like to know, such as mission considerations, control requirements for various segments of the flight trajectory and different types of control effectors. It further gives generalized equations of motion with a novel method of incorporating structural flexibility and propellant sloshing which does not require rederivation, and very easy and common sense approach to deriving slosh and gimballed engine dynamic equations. Subsequently it gives the control system configurations, power plant sizing, loop design for linearised system and detailed analysis and design of on-off reaction control systems. It also covers various software features which are necessary for actual implementation of the design in flight missions, robustness features to avoid malfunctioning in some circumstances, design validation aspects including end-to-end sign checks and describes some flight experiences which called for design updates. The book is unique for its strong practical flavour and is directly useful to the working engineers in the field and post graduate students in Aerospace Engineering. This report documents some techniques used in deriving the equations of motion of a missile for a six-degree-of-freedom (6-DOF) simulation. Several forms of the equations are developed, and their implementation is discussed. Specific emphasis is placed on showing the interrelation of the equation forms currently in use by showing their development from the basic laws. This report is meant to serve as a primer for new engineers and as a reference for all engineers involved in missile flight simulation. A 1982 survey of missile simulation facilities indicated that very little has been devoted to the validation of missile system simulations. Those validation techniques that are used are not standardized, are often ill defined and are generally undocumented. In an attempt to rectify this situation, the AGARD Flight Mechanics Panel established Working GrouP 12 to examine missile simulation procedures and recommend techniques for the validation and universalization of the results of such procedures. This report recommends a simulation terminology that, if adopted, should simplify the validation process. A hierarchical model representation called, 'Confidence Level in Model Behaviour', (CLIMB) is also recommended. It organizes the simulation process and emphasizes a standardized documentation procedure for both simplifying the orderly use of simulation and insuring confidence in the final simulation results. Examples of using the climb model are included. A brief section on computer languages and how they can benefit the simulation process is included. Software verification, validation and assessment methods are examined and recommendations made to enhance the validation of the simulation. Keywords: Missile simulators, Mathematical models, Computer systems programs, and (NATO furnished). Pershing II flight simulations were performed using the U70 missile simulation program to determine (1) in the event of an accidental nozzle deflection, how fast the missile would leave its (safe) flight corridor; (2) how well the U70 aerodynamic simulation matches the actual flight data; and (3) the trajectory profiles for nine Tactical Ballistic Missile flight trajectories. Also an advanced simulation program developed by TRW, Inc. was partially converted to run on an inhouse computer. Test and evaluation (T&E) provides the means for determining to what extent the weapon satisfies its requirements, how well it functions in the operational environment, and whether or not it should continue into production. Among the topics addressed here: performance, flight, simulation, electromag This paper will address several system effectiveness tools developed by the U.S. Army Missile Command's Missile Research, Development, and Engineering Center (MRDEC). MRDEC has expanded upon the traditional lethality modeling tools and methodologies and incorporated novel ideas utilizing visualization and design level engineering assumptions. Effectiveness and lethality were not traditionally included in the early stages of missile system development, but were calculated based on the results of individual component performance. Detailed system effectiveness studies were an after-thought, with a lack of feedback in the missile development cycle. In recent years the MRDEC has worked with PEO Tactical Missiles Project Offices and contractors in refining a process to fully explore a design level approach to missile system development. This paper will discuss mini-map technologies, connectivity of flight simulation performance and warhead performance for missile and/or component development, and new visualization tools to assist the analyst in the accessing and analyzing the computed data. MRDEC is demonstrating that the utilization of design level effectiveness studies is critical in the development of missile system requirements, design, and evaluation. By increasing design level lethality inputs in the development cycle, the overall process can. This game offers horror and flight simulation with full-view in your flight vehicle, in order to zip in and out of mine shafts chasing the enemy. This guide is a necessity for the player because it's very easy to get lost in the tunnels and consists of 30 levels.

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