

GROUND-BASED INTERCEPT OF A BALLISTIC MISSILE

by

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B.A., Indiana University, 1990

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Ground-Based Intercept of a Ballistic Missile

Creative Investigation directed by Professor Charles Fosha

This creative investigation outlines the design and simulation of a Ground-Based Intercept of a Ballistic Missile. The components that made up the simulation were: An Infrared Sensor, Ground-Based Search and Track Radar, Battle Manager and Exo-atmospheric Kill Vehicle. It also identifies the managerial aspects of how a project design and simulation started from the initial plan to the end product, providing a baseline for future projects to follow.

Table of Contents

CHAPTER 1: INTRODUCTION AND PROGRAM MANAGEMENT	1-1
INTRODUCTION	
SCENARIO & COMPONENT DESCRIPTION	1-2
SPECIFIC AREAS OF INTEREST	1-2
TEAM POSITIONS	1-3
SCENARIO	1-3
SEQUENCE OF EVENTS	1-4
COMPONENT DESCRIPTION	1-5
PROGRAM MANAGEMENT	1-8
RESPONSIBILITIES	1-8
SCHEDULE & RESULTS	1-8
RESOURCES & RESULTS	1-9
UNSTRUCTURED MANAGEMENT	1-12
BASELINE METRICS	1-13
CONCLUSION	1-14

Tables

1-1 Simulation Development Stages

Figures

1-1 Spiral Development Process

I. INTRODUCTION

This final report is the formal documentation for the Spring Semester, 1999 ASE 583 *Engineering Simulation* class project. It details the process of the system followed by the simulation team, describes the technical details, the simulation, decisions that were made and the rationale for making them.

The problem addressed the technical issues associated with detection, acquisition, and kill of an incoming ballistic missile. The first chapter outlines the basic project scenario, and gives a non-technical description of the major components. It concludes with managerial issues of scheduling, developmental processes used and baseline metrics for future Program Managers.

II. SCENARIO & COMPONENT DESCRIPTION

SPECIFIC AREAS OF INTEREST

1. Detection
2. Tracking
3. Discrimination (Ground and Air)
4. Communications
5. Sensor Fusion
6. Transfer of Target Information from ground (RF) to
airborne seekers (IR)
7. Vehicle Control

TEAM POSITIONS:

Below, is the list of positions needed to be filled and the team members who filled them:

1. Program Manager: Mark Wert
2. Systems Engineer/Simulation Architect: Tim Fromm
3. Simulation Integrator: Kyle Cone
4. GPS Engineer: Surachai Sukchoo
5. Control Engineer: Scott Klempner
6. Radar Engineer: Brian Egbert
7. IR Engineer: Dan DeYoung
8. Battle Manager: Michelle Roxburgh

SCENARIO

The scenario begins with a launch of a ballistic missile headed towards the United States from inside Europe.

- The launch time is 0000, 1 July 1998.
- The launch point is Paris, France (48.88 degrees N. latitude, 2.43 degrees E. longitude, 0.23 KM altitude).
- The impact point is New York City (40.75 N. latitude, -74.1 degrees E. longitude, 0.23 KM altitude).
- The decoy impact point is Washington, DC (39.0 degrees N. latitude, -77.0 degrees E. longitude, 0 KM altitude).

- The autonomous search and acquisition radar is located at Daqortoq, Greenland (62.0 degrees N. Latitude, -47.0 degrees E. longitude, 0.02 KM Altitude).
- The track radar is located at the same position as the search and acquisition radar.
- The IR satellite locations are at 0 degrees longitude, and -30 degrees E. longitude, in geostationary orbits.
- The Ground Based Interceptor, or EKV is launched from New York City, at the same coordinates as above.

SEQUENCE OF EVENTS

1. Space Based Infrared System detects the booster and provides angles only information to the battle manager. The angles are from the ballistic missile to both of the IR sensors.
2. The Battle Manager provides an azimuth and elevation to the autonomous search and acquisition radar.
3. The autonomous search and acquisition radar establishes a more accurate initial position, and hands this information to the track radar.
4. The track radar establishes a track of the target(s) and provides a track to the Battle Manager (azimuth, elevation and range).
5. The Battle Manager updates the track using a kalman filter, determines the ballistic missile flight path, and sends

position and velocity vectors of the target to the interceptor. At the appropriate time, the Battle Manager launches the Ground Based Interceptor. This happens when the elevation angle of the launch site to the ballistic missile is above zero degrees.

6. The track radar continues to track the targets, attempts to resolve the RV and decoy, and provides target track data to the Battle Manager.
7. The Battle Manager continues to update the ballistic missile track, and send updates to the interceptor.
8. The interceptor continually updates its flight path based on ballistic missile position and velocity updates from the battle manager to guide itself toward the ballistic missile.
9. The EKV uses its on-board radar sensor and the target position and velocity provided by the battle manager to identify the RV.
10. The EKV uses its on-board sensor as well as battle manager RV position information to home in on and hit the RV.

COMPONENT DESCRIPTIONS

The creative investigation definition outlined many of the top-level functional requirements for this application. The following is a description of the components included in the analysis of the ballistic missile defense mission.

The Space Based InfraRed Two Satellite System has the capability to detect the booster, in this case a Minuteman III missile. The Geosynchronous satellites have a scanning detection method similar of that to SBIRS.

The ground radar is modeled after the Ballistic Missile Early Warning (BMEWS) phased array. The ground search and acquisition radar provides surveillance, detection, and discrimination of the incoming target. This system provides location data of the incoming ICBM to the co-located track radar. The track radar further pinpoints the location of the missile and has the capability to discriminate between the reentry vehicle and the decoy.

The Battle Manager is the central 'hub' for communications with each of the components in the system, minus the GPS system. This component receives specific inputs from each component and is coded to translate the data and is forwarded to another specific component. The Battle Manager has the following components:

1. IR Data Processing
2. Launch Message Timing
3. Initial Track Generation
4. Track Updating

The GPS component was designed and developed to simulate the navigation and positioning capabilities used by the Ground Based Interceptor.

The Ground Based Interceptor is a single stage booster and a separate kill vehicle to achieve non-nuclear, exoatmospheric hit-to-kill intercept against incoming objects. The GBI will receive intercept point data from the Battle Manager just prior to launch. The EKV communicates a status report to the Battle Manager via a Communications System thereby alerting the system that it is operational. The EKV will continuously update the ballistic missile position and velocity from the Battle Manager to home on the ballistic missile. The EKV will identify the RV on the basis of discrimination data forwarded by the Battle Manager and provided by the Ground Radar. The EKV homes in on the RV based on directions from the battle manager. It does not do any discrimination itself. The EKV is equipped with a GPS receiver for highly accurate velocity and positioning.

Though not a component, Missile Flight Tool (MFT) provides truth data of a ballistic missile launch to all simulation components. The truth data includes time, latitude, longitude, altitude, latitude rate, longitude rate and altitude rate of the booster and both the actual Reentry Vehicle (RV) and the decoy. MFT communicates with STK using STK's Inter Process Communications (IPC) module. Finally, MFT provides a visual display of the complete simulation, from launch to intercept, or ground zero.

To try and keep project on track and meeting suspenses, the team needed a program manager to facilitate the progression of the design and simulation process.

III. PROGRAM MANAGEMENT

RESPONSIBILITIES

The Program Manager is responsible for management of the overall execution of the program. His/her principle product is the program plan. These responsibilities include:

1. Securing and allocation of resources (budget) to complete the simulation.
2. Definition of the schedules (Integrated Program Plan (IMP) Integrated Program Schedule (IMS)).
3. Recruiting and organization of the M&S Development Team.
4. Maintaining program status.
5. Customer interface.

The primary duty for the Program Manager in this scenario was that of planner, and scheduler. Other important areas that needed to be addressed were managing and obtaining resources, and ensuring the component level managers stayed aware of all others progress over the course of the simulation development.

SCHEDULE & RESULTS

The schedule was initially drafted in early February of 1999. Both the Program Manager and the System Architect coordinated in developing a timeline for system completion. The first stage was the Problem Formulation/Definition for the simulation development process.

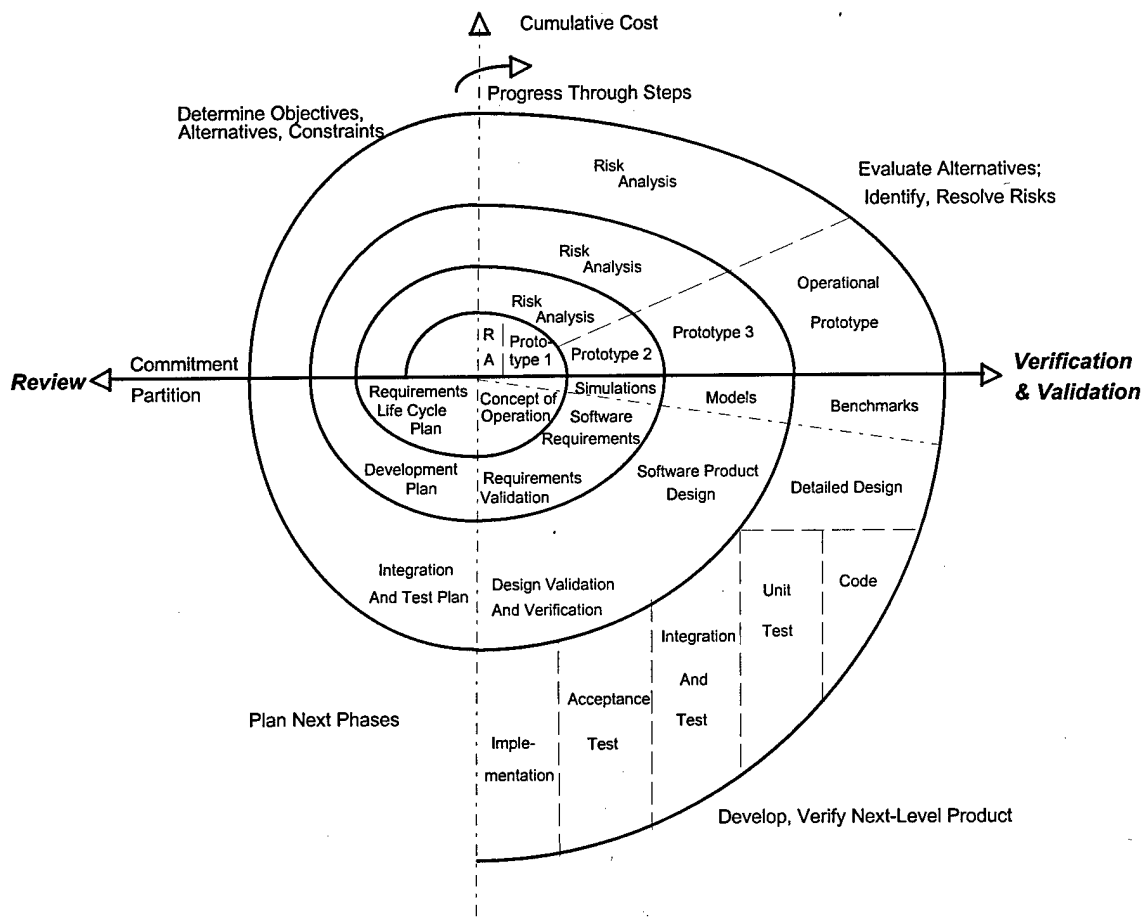


Figure 1-1. Spiral Development Process

The overall schedule for the entire system was drafted based on a spiral development process (Fig 1-1). The dates for the original schedule follow:

Iteration I - 8 to 18 March 99

Iteration II - 19 to 30 March 99

Iteration III - 1 - 11 April 99

As discussed, we tried to plan for the spiral development process from the start, but in reality, ended up resembling the linear process outlined in Table 1-1 at the system level. By the time we gave our Conceptual Design Review on 5 Apr 99, it became apparent that the project was falling behind and we were forced to adjust the schedule. As a result, we had time for only one complete iteration of the waterfall development process for the overall system level. This was mostly due to time constraints resulting from difficulties in running and learning necessary STK modules, and importing and exporting data from each model. Another obstacle in the process was the requirement to brief three times and write up papers.

In contrast, each of the individual subsystem models underwent the spiral development process. Individual models were developed iteratively, first getting the basic system states up and running, and adding functionality and detail over time to improve the model.

Table 1-1. Simulation Development Stages

STAGE	DESCRIPTION
Problem formulation/definition	The definition of the problem to be studied including a statement of the problem solving objective. (Why? What? Goals?)
Develop M&S Requirements	
Project planning	(Can we do it?)
System conceptualization and definition	What to observe in the world?
Model building	The abstraction of the system into mathematical logical relationships in accordance with the problem formulation.
Data acquisition	The Identification, specification, and collection of data.
Check Model Validity	Check that the model represents the system
Model translation	The preparation of the model for computer processing.
Model behavior	Determine how all the variables with this system behave.
Complete Verification, Validation, and Accreditation	The process of establishing that the computer program Executes as intended and of establishing the desired accuracy or correspondence exists between the simulation model and a real system.
Policy analysis and model use	The process of establishing the experimental conditions for using the model.
Experimentation	The execution of the simulation model to obtain output values.
Analysis of results	The process of analyzing the simulation outputs to draw inferences

STAGE	DESCRIPTION
	and make recommendations for problem resolution.
Implementation and documentation	The process of implementing decisions resulting from the simulation and documenting the model and its use.

RESOURCES & RESULTS

Obtaining the appropriate resources presented a large problem at the system level. There was only one computer for all modeling inputs to be made. This resulted restricting the ability of team members to make their inputs on a timely basis. *Satellite Tool Kit* presented problems as well. The use of STK was needed to obtain a truth model for the system. However, it was found that we did not have the correct licensing for STK. Once it was obtained, it was discovered that STK did not represent a ballistic missile in flight correctly, causing considerable delays for the Simulation Integrator to establish truth data for the system. It was another three weeks before Missile Flight Tool became available for use and the correct software was implemented into the system.

UNSTRUCTURED MANAGEMENT

It was my intent to involve myself with every aspect of this project. The attempted was made to work with everyone on their particular area of expertise. This simply became too much work

for the time available. Also, due to time constraints, it was best to try to keep this project as informal as possible. We did not want to get the group bogged down with meetings and status reports while learning the design and simulation process. The schedule was set to follow the spiral development method for model building and checked in with everyone as much as possible, and eventually started to see progress being made. However it was not going as fast as we had originally thought it could.

Early in the process, weekly meetings were set up to discuss the progress of the simulation. The weekly meetings changed to coming in and working for six hours a week when the team started falling behind the original schedule even further. Maintaining charts with *Microsoft Project* to keep the team abreast of how they were progressing against the schedule would have been a more efficient way to manage the project and would have given them a tangible goal to shoot for. Most importantly keep the team members in communication with you and each other.

However, due to the nature of the project coupled with critical lessons that did not occur until late February, the team progression would still be at the same level regardless of management techniques.

BASELINE METRICS

This is a baseline for any attempts for future projects. The estimated completion time under the conditions we were given

would be approximately 10 to 12 weeks to finish the simulation. This timeframe allows for the necessary time to plan, design and eventually simulate. It also provides for built in stops to allow for briefings and writing of papers for the course. The key for this type of project is to get all the information required for designing and developing a simulation at the beginning of the semester. The Program Manager should set up the first planning meeting within the first week of the start of the project. The schedule should be set up for one complete iteration, the linear waterfall, at the system level and maintaining the spiral development process at the component level.

The Program Manager should make this a job versus a class project. This project requires at least 4 hours per week per individual team member to finish in the allotted timeframe. This method will keep team members in communication both vertically and laterally.

IV. CONCLUSION

The system design and simulation of a Ballistic Missile Interceptor was more complicated than was originally thought. From a Program Management standpoint, one must get started early and have a good understanding of the simulation development process. Under the given circumstances with which to work, time was the critical driver for successful completion of the project

and was what the team had least of. It is also imperative to have not only the right resources, but also enough of those resources to allow every team member access for their individual component work. Know the development process before you start building. The project is too involved to try to build as you learn given the time constraints.