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# Final Report

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| Contact Name | **Steven Knudsen** |
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**Progress Report Instructions**

1)Complete all sections of the progress report.
2)Submit a signed copy electronically to both the Program Manager and Contracts Representative within ten days of contract end:

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# Final Report, NASA IR 1367

Prepared by GridOptZ

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5)Casey Corder
6)Matt McMahon, MSM Consulting

## Introduction

This final report summarizes our research findings, provides detailed reports of our research findings, discusses lessons learned, and outlines our plans for follow-on research. No explicit commercialization plan is provided at this time, but our team does intend to use the progress we have made as we continue to seek contracts for research. Mr. Knudsen in particular will seek out potential clients for the G2EX who want to employ him as a consultant. This document contains the summary of research findings and a discussion of each deliverable and how we achieved it.

## Summary of research findings

The NASA-IR-1367 project consisted of two tasks, the Genetic Algorithm (GA) Task and the Rotating Space Elevator (RSE) Technology Task. The first task promised software that would implement genetic algorithms on the Global Grid Exchange (G2EX) for the purpose of optimization. Existing code simulating the RSE was to be ported to Java, and then run on the G2EX as a benchmark. However, it became apparent early that genetic algorithms are very general, and we needed more information to make them work well specifically with the RSE. So, the RSE Technology task label was applied to the RSE work, and more effort was applied to understanding the RSE theoretically.

To this end, the WVU subcontract was increased from $10,255 to $15,000 to allow Dr. Golubovic more time to work on the theory. This increase was well rewarded with results showing a "super-stable" solution to the RSE at a frequency about twice the minimum frequency $\omega_{min}$ needed to maintain climbers rising on the elevator. These results concerning the possibility of everlasting stability of the RSE motion are detailed in our March report. This report in turn rests on earlier reports that laid the foundation of understanding the RSE.

Our team was successful in making a usable GA Optimization package (GAP) and testing it with our RSE benchmark code. Dr. Golubovic's success with the RSE Technology has given us greater insight in how to move forward towards getting useful results from the grid. The grid works best when the small data sets that it sends back are well understood, which is why we have depended so heavily on single machine computation during this phase of the project. In the final months we demonstrated using the GGE to compute six days of data for an RSE with a high density mesh. The results were consistent with single machine computations, and therefore we have great confidence as we proceed to the next phase of our research. For further research, we will implement Dr. Golubovic's suggestion on how to use the grid to compute RSE motion, and then by proper filtering and measures of stability, find the essentials of the motion. This kind of insight could not have been obtained without the increased focus on the RSE itself.

The GAP package presently computes RSE dynamics and sends back scores indicating how optimal a particular parameter set (relating to the RSE design) is relative to some scoring strategy. The code at this time has only minimal post-processing capabilities. In anticipation of the need for more sophisticated post-processing, the capability of reading and writing NASA formatted (HDF and HDF5) files was added. We studied this issue and presented the results of our progress at the final technology demonstration. Initially, we planned to have these tools installed as utilities on the grid. However, instead we installed the tools locally, and in any consulting work or distribution of our software, we would make these tools available to other users. This is a simple solution, and avoids the need for transferring large quantities of data over networks. Our grid computing was done on the G2EX, located in Fairmont, WV, and we thankfully acknowledge the generous contribution of computing resources from WVHTC Foundation.

The discussion of research findings is broken down as follows:

1)Dr. Canning's report on the GA Task, and how his theory and prototype code helped the actual production of the GAP

2)Mr. Hamilton's discussion of developing the GAP, and the lessons learned along the way, particularly concerning the use of the Parabon Frontier Grid Engine

3)Mr. Hamilton's progress with file formats, particularly the HDF and HDF5 formats used by NASA, and the plotting program (Yorick) used to access the data

4)Mr. Hamilton's setup of Eclipse as a integrated development environment for computing on

the grid

5)Dr. Golubovic's method for quantifying stability from early time series data.

6)Dr. Golubovic's summary of accomplishments this past year.

7)Dr. Golubovic's and Mr. Knudsen's plan for integrating the RSE Technology progress and the GAP towards achieving scientific results and peer-reviewed publications concerning the stability region discovered by Dr. Golubovic. This corresponds to a proposal for further research and indicates prospects moving forward.

The lessons learned are indicated in the reports, particularly those of Mr. Hamilton. The commercialization plan is embedded in Dr. Golubovic's and Mr. Knudsen's plan for integrating the RSE Technology progress and the GAP.

The final report is broken into three pieces, this summary file, a compendium of the RSE Technology appendices from prior reports (RSEcompendium.doc), and a file containing the detailed reports (detailedreports.doc).

Finally, we list the deliverables, organized under the headings "RSE Technology" and "GA Technology" and briefly comment on how well we fulfilled these goals.

## RSE Technology

We consider the RSE Technology task to have met all benchmarks, but these have led us to see how much more research can be done on the Golubovic RSE as an intriguing technology for propelling payloads to space. Clearly, more work needs to be done on suitable materials, and also on suitable topologies for such an elevator, but this theoretical and computational work has laid a good foundation for future efforts. The percentage of the sub-grant money spent on this task was 41%.

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elevator,

Task 2a). Complete a parameter study and find optimal solution, using physical insight

The grid confirmed that Dr. Golubovic's theoretical work is "one step ahead of the grid". The final report outlines the next steps, and these involve use of the G2EX.

Task 2c). Complete a parameter study and optimization using genetic algorithms

The alpha version of the GAP is being tested on realistic problems needed for understanding the RSE, based on instructions from Dr. Golubovic. Reports were made of progress on the RSE using mainly single machines running C++ code, but further preparations are being made for non trivial deployments to the grid. Careful work on single machines is essential before trying large deployments on the G2EX. Say grid was used successfully at end!

## GA Technology

The core goals of this task were completed, particularly with the finishing of the alpha version of our genetic algorithm package (GAP). The percentage of the sub-grant money spent on this task was 44%, leaving 15% of the money for administrative tasks and expenditures on equipment.

Task 1a). Port demonstration code to JAVA ™

Completed during July.

Task 1b). Do performance testing

We are running tests of the GAP, doing significant studies of the aging of the Golubovic RSE, as discussed above. Our final report describes our plans for deploying to the G2EX.

Task 2b). Build lightweight genetic algorithm (GA) package used on local machine which invokes local grid simulator and remote grid model

Mr. Hamilton and Dr. Canning produced the alpha version of the GAP that Mr. Knudsen is now testing!

Task 2x). Get started with machine and on grid (MSM Consulting)

-- this was completed before May. Mr. McMahon was paid upon receipt of payment from WVHTF for March/April.

The next three tasks listed below were explored by Mr. Hamilton in the final month of the project. His progress is discussed in the HDF section of the final report.

Task 3a). Implement existing JAVA ™ technology for HDF file formats into a local JAVA program

Task 3b). Implement existing JAVA ™ technology for HDF file formats for data from local grid mode (LGM)

Task 3c). Implement existing JAVA ™ technology for HDF file formats for data from remote mode)

Task 4a). Set up and test a simple messaging system using JAVA ™ technology

Since the purpose of the messaging task was to promote communication among collaborators for Next Generation Space Exploration (NGSE), we believe that our progress with the Mantis concurrent versioning system and our use of Eclipse environment for computing and demonstration fulfills this purpose. The Mantis concurrent versioning system allows our team to share code with one another, and keep a record of bugs and comments concerning code. There is no reason why access to this system can't be shared with other trusted partners, so this really is the beginning of communication among researchers interested in NGSE. Also, the Eclipse platform is becoming a standard for open source collaboration, so again our efforts in this area are consistent with the purpose of the messaging task. We have also made every effort to document what we have learned about our software along the way, and so this also is in keeping with good communication practices.

Task 5a). Examine, experiment, and report on the use of native codes with only an "interface" to the grid for post processing and test for speed and accuracy

Based on the security elements of the G2EX, we were not able to use native codes. However, it

was simple to port our code to the G2EX framework, and it ran acceptably fast. As Parabon's technology improves, and they allow increasing use of native codes, we will revisit this issue.

**By signing this document the Project Manager declares that the information provided in this report is true, complete, and accurate and gives consent to the West Virginia High Technology Consortium (WVHTC) Foundation or parties representing the WVHTC Foundation to verify any information provided in this report.**

Steven R Knudsen

_____ Date: 4/14/2008

Project Manager