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Development of Space Robotic Force Moment Sensor

Date: February 19, 2010
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Executive Summary

A force moment sensor (FMS) informs a robot to sense how hard it is pushing/pulling/twisting. When present, it is normally positioned between the end effector (hand) and wrist. Only a small number of robots are equipped with FMS. The terrestrial demands of FMS are significantly different that those for space. Which largely explains why the development of a space robotic force moment sensor (FMS) has been eluding the space community for over 25 years. Canadarm (shuttle arm) does not have a FMS. Canadarm2 has FMS, but reliability is problematic for operations lasting more than ½ hour. A FMS has applications in both manned and unmanned space operations.

The space environment in combination with the operational demands for a space robot have made its development a difficult problem. Then there are also ‘management issues’. One of the problems is that the cost and schedule for the development exceeds what engineering program managers at a single systems supplier are willing or able to invest. The second issue is the apparent simplicity of the problem.

A space FMS development demands specialization and long term commitment. It can be developed as a stand alone product, to be sold to a variety of space systems developers, or kept exclusive to a single customer. As a ‘new product’, expected sales had been expected to be non-existent during the multi-year development phase. Our new sequence of product development has changed that. Sales and marketing will begin with a simulator product, for insertion into a robotic control test bed.

Space robots such as the Canadarm’s receive public attention - when they’re in a civilian space arena with cameras. They move, and perform counterintuitive tasks. The ability of the robotic control systems to substantially improve performance is being inhibited by the lack of a space robotic force moment sensor. Robotic controls engineers are frustrated.

As a product, FMS represents a highly concentrated niche, for a long term product to both the human space flight and the on-orbit servicing market. An optimist might perceive that an exclusive FMS capability could lead to capture of sales of entire space robotic systems. Or at least to a very profitable exit strategy.

The complexity of the FMS solution guarantees that production will remain with the expertise. The need for a complex solution has been validated by the number of international failures to produce an adequately functioning space robotic FMS.

The initial development costs of the FMS are substantial, for a limited expected annual sales revenue. The market is limitless in duration. By combining advanced marketing with simulator development, we have conceived a means of partially funding development with near term sales.

After having spend the recent 4 months, scrutinizing our previous test data, new technical insight into our solution has driven the re-issue of this technology development plan.

Table of Contents **Page**

1.0. Good Vibrations Engineering Ltd. (GVE)

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1.1 Profile

Good Vibrations Engineering Ltd. is a privately held, Canadian company.

Sherry Draisey is owner and operator. The other staff members: Noah Mullins and Mayes Mullins.

1.2 Applicant R& D

The proposed R&D initiative is for development of a Space Robotic Force Moment Sensor. It is the continuation of development of a sensor concept, originally patented by Sherry Draisey/SPAR Aerospace in 1992.

During the 90's we received IRAP funding to build a 3 degree of freedom configuration, and some additional funding from the European Space agency to partially test it.

The originally filed patent has now expired, but there is substantial new IP being developed in two areas: the non-linear analysis tool and the force algorithm software - the conversion of frequency shift and modal information to force levels. The concept is summarized in a technical paper on our web site: www.gve.on.ca/cctomm.pdf , though it does not reflect our recent and improved insights.

We began work March 1, 2009 and expect to complete it Sept 30, 2014. Since 2009 there has been one technical 'discovery', one management 'discovery' and one marketing 'discovery'. The technical discovery relates to our understanding of the non-linear stiffening of the structure, and its enhanced force resolution implications. The discoveries have required this development plan revision.

1.3 Need for External Investment

For many years, we considered external investment mandatory for FMS development. More recently, we have devised an approach that could self fund some of the long term development costs, but it will be much slower than that which external investment could provide.

A space robotic force moment sensor represents a stable, long term product to the space sectors - civilian and defence. The FMS is a subsystem with applications in a wide variety of space robotic operations, with very long term sales potential. The fairly simple interface between our FMS and the systems it will be needed in (both the physical and computer interface) make it a good candidate for overcoming ITAR limitations. Thus we expect to tap into the military economic recovery deficit that Canada has with US suppliers. We have had cursory discussions with some of them.

Our initial costs of the R&D and associated capital costs are substantial, but we now anticipate we can generate simulator and engineering service sales over that period.

The nature of the FMS subsystem is such that no single systems supplier has the need to support the development of the force moment sensor. That could change, as the industry grows, and there is competition between space robotic suppliers. But for now, it is prospective sales to a wide variety of customers that warrant the initial expense (similar to aircraft landing gear - but with cleaner interface, and lower production volume). We anticipate annual sales of the device to be about twice the order of our initial development costs.

A Canadian company clearly has the initial advantage in selling such a device - because of our success with the Canadarm's. The Canada Space Agency may well be our first customer. They are finally beginning to show some interest.

Until recently, as a small company, we did not have the financial resources to support the capital outlays needed to continue our FMS development. As a result of re-sequencing our product development approach, and utilizing our existing expertise, we are actively now supporting the development organically, for this year.

The initial product that space robotic controls engineers need is a good simulation of the FMS device - to include in their test beds. That is cheaper for us to produce, than fully tested FMS hardware. For us, the most prohibitive cost is the test rig hardware.

We had expected it to take 4 years for our complete development. But we are now targeting first generation simulator development, to be completed in one year. We anticipate generation of service sector sales within 6 months of the simulator product availability.

Our ability to make sales to the U.S. military market has been substantially improved with Canada's military procurement return policy. We have already been in preliminary discussions with American contractors, interested in obtaining a space robotic force moment sensor. There is no one in the world building them.

2.0 Statement of Work

2.1 Overview of the Work

The goal of the work is the development of a pre commercial unit space robotic force moment sensor - both the hardware and software simulations of the unit. The approach to the work is parallel progress, alternating between analytical and experimentally driven development. This will allow for the demonstration of resolution capability for all 6 degrees of freedom force. The simulation product will provide customers with a low cost means of evaluating our FMS subsystem, within their system, at an early stage of their project (possibly even at their proposal stage).

2.2 Description of Major Activities and Expected Outcome

Table 2-1 presents the performance goals that the precommercial unit is to be designed to meet. Figure 2-1 provides the work breakdown structure for the plan to achieve these goals. The project schedule of section 2.3 is based on the work breakdown structure. The tasks of the WBS are defined based on the WBS.

Performance Characteristic	Max	Min
Measureable Force	400 N	2 N
Measureable Moment	350 Nm	1.5 Nm
Allowable Drift (10% of measurement)	8 hours	n/a
Rotational Stiffness	67.7e3 N-m/rad	35.e3 N-m/rad
Surviveable Force	600 N	n/a
Surviveable Moment	500 N-m	n/a

Figure 2-1 Work Breakdown Structure

FMS
WBS 100

B/B; 110	Non-lin s/w; 120	Pre-Com; 130	Calibration; 140	S/W sim; 150
111. System Specification	121. Matlab 3 dof	131. System Specification	141. System specification	151. Free Version
112. System Design	122. Valid 3 dof	132. System Design	142. System Design	152. B/B update
113. Mechanical System	123. Matlab 6 dof	133. Mechanical System	143. Mechanical System	153. Pre-Com update
114. Microprocessor System		134. Microprocessor System	144. S/W control system	154. Service version
115. Force algorithm s/w		135. Force Algorithm s/w	145. Neural Network Dev	
116. Initial Testing		136. Calibration Testing	146. Manufacture	
			147. Verification	

Table 2-2 Tasks for Breadboard Unit

WBS	Task Title	Task Description
110.	Breadboard Development	The extension from 3 force degree of freedom (dof) concept to 6 dof. Though there may be an eventual need for a more advanced poling concept for the piezoceramic driving and sensing system, we will explore our existing poled ceramic more extensively for its ability to excite all 6 dofs. The tracking system will no longer be based on the ceramic sensor, but we will build in accelerometers. This will increase our driving system options, and improve our tracking of frequency shifts, which will lead to better force resolution.
111.	System Specification	The breadboard unit performance goals and physical configuration will be specified, for design goals, and performance evaluation.
112.	System Design	The overall mechanical, electronic and software implementation will be defined, at least in block form. This will also provide the external interface definition of the system interface to the test equipment, as well as to the larger space robotic systems it will be needed for.
113.	Mechanical System	The mechanical system will consist of a housing, a piezoceramic driving unit and accelerometers. The housing will be developed as drawings and sent out for manufacture. The existing poled ceramics we have in house will be used. We will purchase at least 2 more accelerometers to add to what we have in-house. Computer models will be generated to evaluate performance characteristics, to allow for some optimization. These computer models will be used to support the simulator product development.
114.	Microprocessor s/w & electronics	Existing segmentially poled piezoceramic elements will be driven with the existing electronics system to produce distinct modes shapes at the system resonant frequencies. We have developed a 3 dof driving system using a DSP, though the processing time is a little on the slow side. This will be modified in an attempt to adequately drive each of the 6 dof's needed. For the breadboard system, we will continue to focus on driving and tracking the modes, rather than processing speed.

115.	Force Algorithm	The force algorithm software is the conversion of frequency response functions to 6 dof force levels. We have an existing system of 3 dof prediction, but this will need to be revised to reflect the new breadboard h/w and accelerometer configuration. The accelerometers are used to monitor the frequency response of the mode shapes - including their modal coefficients. It is this combination of modal frequency and coefficient tracking that allows for the transduction to force. The force algorithm is the software that acquires responses and converts them into force information. This algorithm will be developed to a MATLAB piece of software only, at the breadboard level.
116.	Initial Testing	The non-linear nature of the force moment sensor is fundamental to its function. The breadboard testing will be limited to tests needed to validate the unloaded structure, plus a few, loaded configurations, to support the simulation software.

Table 2-3 Tasks For Non-Linear Analysis Software Tool

WBS	Title	Task Description
120.	Non-linear, normal modes software module	A matlab routine to predict the modal characteristics of the structure under varying load conditions is being developed. It is a combination of partial differential equations to reflect the two stiffening mechanisms involved near the strut connections, and then the knitting together of these results with special purpose FE models. This tool is needed for two reasons - to support the design and as a key algorithm in the simulator product.
121.	Matlab 3 dof	A matlab routine, is in progress to model the stiffening nature of the system. The axial degree of freedom has been completed. The extension of this to the two moment degrees of freedom is based on the same approach - only quadrant sign changes will be needed.
122.	Valid Matlab 3 dof	The routine software will be evaluated against the existing 3 dof test data available. Modification will be made as appropriate. The test data frequency shifts are based on modes high enough to avoid b.c. sensitivity.
123.	Matlab 6 dof	The 3 dof software will be extended to predict the full 6 dof effects. The approach should be fairly accurate for the torsion condition, but less so for the two shear directions.

Table 2-4 Tasks for Pre-Commercial Unit

WBS	Task Title	Task Description
130.	Pre-Commercialization Unit Development	The results of breadboard development will allow us to correct and refine the design to meet a generic design for a space robotic force moment sensor, suitable to the autonomous or semi-autonomous robot operations needed for satellite servicing. This may involve changes to the poling concept for the piezoceramic driving and sensing system. It will require a modified approach to securing the piezoceramic element within the housing. It will require modifications to the driving and advanced tracking system to correlate frequency shifts of multiple modes to each of the relevant degrees of freedom. It will also require significant effort to increase the speed of transduction (reduce the latency). It may also include changes suggested by users (potential customers) of our first generation simulation system.
131.	System Specification	The unit performance goals and physical configuration will be specified, to meet design goals, and for performance evaluation. This information will be made available publicly, to allow for input from potential customers
132.	System Design	The overall mechanical, electronic and software implementation will be defined. This will provide the external interface definition, in the form of ICD (interface control document) the system will interface to the space robotic systems it may be implemented in, for force moment accommodation control
133.	Mechanical System	The mechanical system will consist of a housing and a piezoceramic driving/sensing unit. These systems will be developed as drawings, to be sent out for manufacture and as computer models, to evaluate performance characteristics, to allow for some optimization within the design process. The computer models will also be used in establishing verification criteria from eventual measured test data, and to support end item calibration data sheets. The precommercialization mechanical system components will be sent out for manufacture and then be integrated.

134.	Microprocessor s/w & electronics	The piezoceramic elements will be segmentially poled, to allow for exciting and sensing various mode shapes of the system. A microprocessor and electronics system is required to drive the element segments to produce distinct mode shapes at the system resonant frequencies. The breadboard microprocessor system will be upgraded to meet performance goals. As a minimum this will involve a move to real time processing - as defined by frequency response criteria.
135.	Force Algorithm	The force algorithm will be upgraded from the b/b matlab force algorithm software that uses acquired accelerometer responses to piezoceramic oscillation and converts them into force information. This algorithm will be modified to meet mechanical characteristics of the precommercialization unit, as well as upgraded from the breadboard MATLAB software , to a faster processing language.
136.	Calibration + Thermal Testing	The non-linear function of load vs frequency will be defined, with measured data along the 6 dof forces involved, as well as influence of coupling between degrees of freedom. The non-linear nature of the force moment sensor is fundamental to its function. This testing sequence will also include thermal conditions (unit temperature changes, as well as thermal gradients across the sensor) to illustrate the sensitivity of the system to boundary condition changes. The calibration testing will be supported by a special purpose test rig. It is possible that neural network analysis may assist in reducing the testing time needed.

Table 2-5 Tasks for Calibration Test Design & Rig

WBS	Task Title	Task Description
140.	Calibration	The calibration test rig will have two roles - one in the initial development of the non-linear sensor, the 2nd as a calibrator for each sensor built The rig must be capable of allowing for fairly rapid load applications, up to fairly significant (and thus safety is an issue) levels, because the loads will have to be applied many times. A review of the potential of neural networks to minimize the number of required test sequences will be performed (with have had some discussions with university partner for this). The system may have to be capable of specifically applying a defined set of independent loads, as well as defined coupled loads. It will be necessary to have an accurate means of determining the load levels that are being applied. It will also be necessary to have a means of applying thermal loading conditions to the FMS unit (breadboard and pre-commercialization)
141.	System Specification	The test rig performance goals and physical configuration will be specified, for design and for performance evaluation.
142.	System Design	The overall mechanical, electronic and software implementation will be defined.
143.	Mechanical System Design & Analysis	The mechanical system will consist of a secure grounding interface, a means of quickly applying and changing out the applied loads and means of verifying the level of the loads being applied. These systems will be developed as drawings, to be sent out for manufacture and as computer models, to evaluate prospective performance characteristics, and to verify safety margins. The computer models may also be used in establishing verification criteria for the applied loading levels. The test rig mechanical system components will be sent out for manufacture and then be integrated. The system will be designed to allow for the addition of some simple thermal loads - either with convective or radiative means.
144.	Software & Electronics	The loads being applied may be based on physical weights, or on actuators, or a combination. A trade off of the feasibility of these options will define how much electronics will actually be needed. The software will also include a means of verifying the load level being applied to the FMS. It must also be capable of applying pure loading dof , as well as selected coupled loading dof.

145.	Neural Network Dev	The non-linear nature of the FMS makes combined loading cases particularly difficult to consider. Evaluation of the use of neural network algorithm will be performed to minimize the number of high load level tests that must be performed
146.	Manufacture & Integration	Some of the test rig mechanical system components will be sent out for machining, some will be directly procured, others produced in-house. They will be integrated in-house.
147.	Verification	Load level application verification of the test rig will be performed to validate the design.

Table 2-6 Tasks for Simulator Software Development

WBS	Title	Task Description
150.	Simulator s/w	a software system to simulate the FMS which accepts commands from a robotic control system, and provides information back to it is needed to allow customers to develop their space robotic control system, in advance of hardware implementation. It will be written in a standard language, which may or may not be platform independent. A review of elements of input and output requirements of interest to controls engineers will be undertaken.
151.	Free version	write s/w simulator that allows for simple interface to imbedded hardware that the FMS will be used in. This initial simulation will not include thermal effects, and will only be partially validated (against available test data). Place executable on web page. Develop a means of recording user comments.
152.	B/B update	upgrade initial simulator as b/b test data becomes available. This version will be used to support in-house consulting services related to potential FMS app's.
153.	Pre-Com Unit; update	update b/b simulator versions to reflect actual precommercialization unit test results
154.	Service Version	upgrade pre-commercial unit simulation to for sale to FMS customers

2.3 Project Schedule

Figure 2-2 is a summarized GANTT chart and Figure 2-3 provides a detailed version.

Figure 2-2 Summarized GANTT Chart

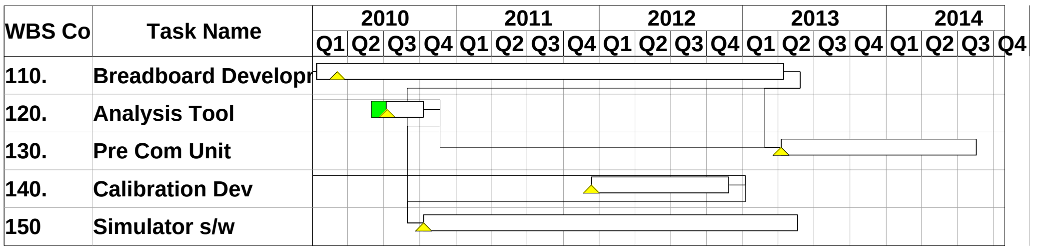
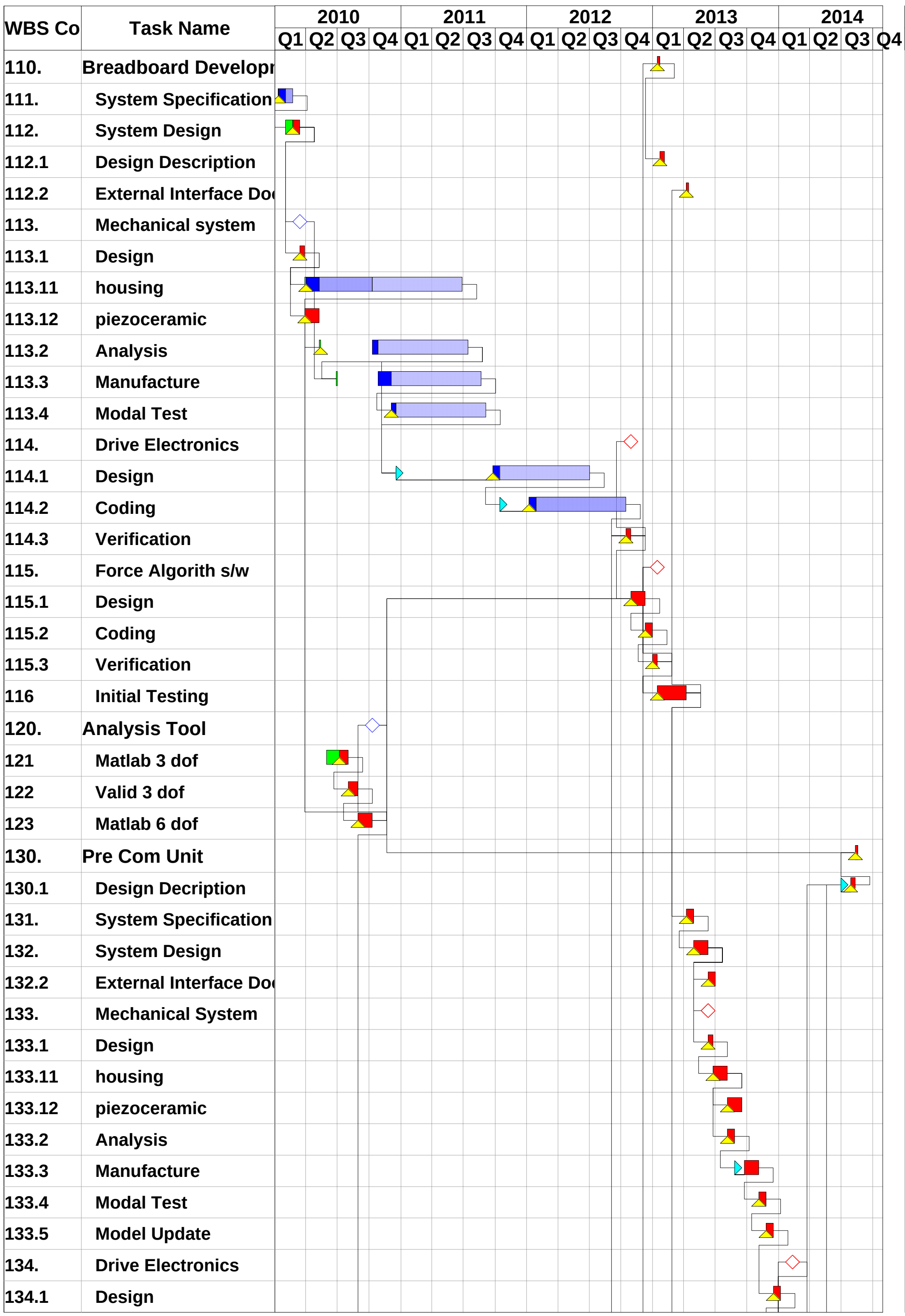
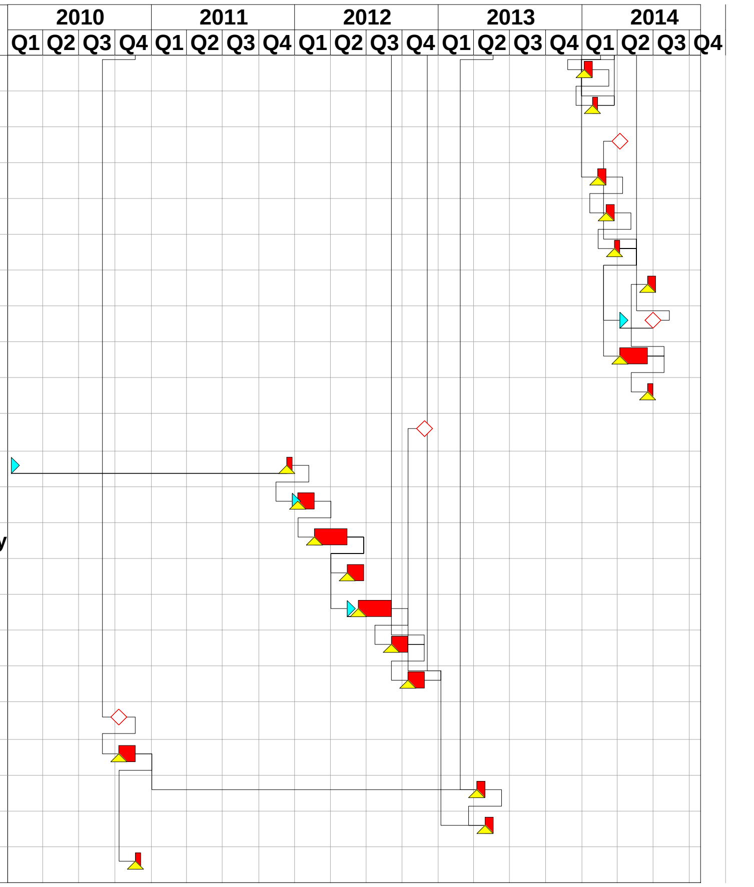


Figure 2-3 Detailed GANTT Chart



WBS Co	Task Name
134.2	Coding
134.3	Verification
135.	Force Algorithm s/w
135.1	Design
135.2	Coding
135.3	Verification
135.4	Update force s/w
136	Calibration Testing
136.1	6 dof loads
136.2	Thermal
140.	Calibration Dev
141.	System Spec
142	System Design
143.	Mech Design & Analy
144.	Software Design
145.	Neural Network
146.	Manufacture
147.	Verification
150	Simulator s/w
151	Free Version
152	B/B update
153	Pre-Com update
154	Service Version



2.4 Cost Breakdown

WBS	Task	Labour	Material
110	Breadboard Unit	974,000	40,000
120	Non-linear Analysis Tool	424,000	
130	Pre Commercialization Unit	932,000	17,000
140	Test Rig	618,000	300,000
150	Simulator software	210,000	
	Total	$3,668,000.	

2.5 Anticipated Net Cash Flows by Calender Year

WBS	2010	2011	2012	2013	2014	2015
110	-80,000	-440,000	-434,000	-60,000		
120 service income	-100,000	- 24,000 +25,000	- 50,000 +25,000	-50,000 +50,000	+50,000	
130				-600,000	-502,000	
140			- 218,000	-700,000		
150 sim s/w	-60,000		-140,000 + 80,000	-10,000 +80,000	+80,000	
production unit						-185,000
partial 1st unit sale						+250,000
Total	-240,000	-441,000	-617,000	-1,290,000	-372,000	+ 65,000

2.6 Project Location

The work will be performed primarily at Good Vibrations Engineering facilities at 65 Carl Hall Road, Toronto, Ontario M3K 2E1 (Downsview Park). At present we have 700 square feet of office space and 350 feet of ground floor integration area. It would be necessary to rent some additional integration facilities, but there is more room available at our Downsview Park location.

Downsview Park is a federal park, within an economically depressed area of Toronto. It greatly encourages organizations which can provide high value employment or training opportunities to the adjacent communities.

Downsview Park is additionally very well served by public transportation. It is located within 5 km of two engineering aerospace university groups (York and U of T's UTIAS). We anticipate on of the development tasks (Neural Network study, part of WBS 140) would be ideally suited to a PhD candidate.

The machining efforts needed for both the test rig and the 2 FMS development units would be subcontracted out to two of the local machining groups we currently work with.

3.0 Company Capability

3.1 Management

Good Vibrations Engineering Ltd. has been combining their consulting engineering work (structural, thermal for space and geophysical developments) with in-house technology development projects since the company began operation in 1992. The company has reinvested all possible capital into development projects, all with an element of space focus. We have been ready for the space world to return interest to ISS and to an eventual Mars destination

Sherry Draisey managed 12 engineers, while she was manager of Canadian Space Station Project Structure group at the former Spar Aerospace. During the 90's, GVE's reached a staff size of 6. Sherry's long term obsession with people has resulted in a strong intelligence network in the North American space sector.

Mayes Mullins, also a former Spar employee, had a maximum staff of 90 while he was Manager of Mechanical Engineering. While Mayes is certainly capable of management of larger projects, his preference is in the technical area - and that will be his role in this project.

During the 90's Sherry also acted as a technical consultant to Canada Revenue Agency's SR&ED program - which has given her expertise in that program. In a short career, prior to engineering, Sherry's job as a pension clerk at London Life gave her a better respect for the importance of administration than is normally present in engineers.

One of Good Vibrations Engineering Ltd. recent management developments is our 'virtual boss'. 'He' has already focused our work to the discovery of the improved performance we can anticipate from the mechanical configuration of our FMS system. Often, a boss or direct customer is needed to provide adequate motivation for difficult tasks and decisions. In the absence of such a figure, we have developed a 'virtual boss'. The concept is consistent with the 'open' applications that are unfolding. Our 'virtual boss' consists of placing the development plan on the web, and publishing a monthly report on the web, reporting progress. So far, this has been amazingly useful. We anticipate it has the additional advantage of providing a market outreach to prospective customers.

3.2 Technical

Sherry and Mayes have kept abreast of technology, partially through the consulting work they perform, but also through active participation in technical conferences and technical journal.

They are both particularly capable in the project proposed;

- have extensive space robotic experience (Canadarm's), particularly in the area of structural dynamics (modal analysis).

- current geophysical consulting work is very similar in application to the test rig needed for the calibration of the FMS.
- The piezoceramic sensing element needed for the FMS is similar to a former project they developed for the DND lab in Halifax (ultrasonic destruction of micro organisms), and later applied as a project for the European space agency.
- built and tested two earlier space robotic FMS prototypes. The most successful based on the piezoceramic transduction method proposed here.
- engineering simulator developments for mechanical applications; example of 3 included on our web pages

Our proposed project is an extension of work initiated by Sherry while she worked at Spar. The patent was eventually turned over to her, after she left the company. She furthered the development of the concept through an IRAP project and subsequently with a European space agency (ESA) study.

Cursory review of the ESA test data we acquired has been a bit puzzling to us. Having implemented our 'virtual boss' concept has focused our technical efforts to finally understand what effects were generating that tantalizing data. The realization was both positive and surprising.

3.3 Financial capability

Good Vibrations Engineering Ltd. is solely owned by Sherry Draisey, and has no debt, beyond a shareholder loan (<$100,000). Our maximum monthly cash flow has been in approximately $40,000. But it has been much more modest in the last few years.

3.4 Financial Status

3.4.1 Projected Financial Statements

Table 3-1 is for the FMS project only. Numbers represent dollars.

	2010	2011	2012	2013	2014	2015
On-hand			-11000	29600	36400	147400
Cash Receipts						
Loan	0	400000	600000	1000000	200000	
CRA SR&ED	0	0	185600	336800	568000	200800
IRAP		40000	40000	40000		
Int R&D	12000	12000				
Shareholder loan	240000					
Simulator Sales			80000	80000	80000	
FMS Sim Cons		25000	25000	50000	50000	
FMS sales						250000
	252000	477000	919600	1536400	934400	598200
Dispursements						
Long Term Debt					25000	50000
R&D	240000	464000	842000	1420000	502000	
Marketing				20000	100000	100000
Operations	12000	24000	48000	60000	60000	100000
Manufacturing					100000	285000
	252000	488000	890000	1500000	787000	535000
Taxes -						
Ending Balance		-11000	29600	36400	147400	63200

3.5 Cost tracking / accounting system

Cost and schedule will be tracked using our Scitor Project Scheduling software.

3.6 Business plan

Our business plan is available under separate cover. It includes this project, as well as our other products and services, including our vestibulator product, which we are now exporting to the U.S.

Production of each FMS will be done with the same in-house team as is needed for this R&D exercise. Each unit will take on the order of 6 months to 1 year to produce - because of the sensitivity to calibration issues.

The unit size is quite small (< 5 kg, <1000 cm^3) so there are no significant storage challenges. Only the test rig takes up any significant space. Machining will continue to be subcontracted out locally.

Distribution issues for small size, small volume products are limited. There will be times when we package and ship with a courier, and other times when a staff member will personally deliver the device to the customer, to help with its integration.

3.6.1 Preliminary market analysis

Table 3-2 provides a preliminary market analysis of the concept. It is difficult to establish all market analysis for a product that is not yet available, and is needed by aerospace groups - they are rather secretive.

Table 3-2 Market Analysis Table

Question	Answer
Market Definition	Civilian aerospace (Canada, JAXA, ESA) American Military
Companies in the market	JR3 - not suitable for space needs MDA - have shown interest as a partner to us
Are other companies servicing this market with similar product?	no
Is the market saturated or open?	open - no device has proved adequate yet
Market size: 1) FMS hardware 2) FMS simulator software 3) FMS simulation consulting	 1 space unit per year; 2-4 equivalent for test beds 2–5 systems per year 1-2 contracts per year
Is it a growing market?	yes - has been slowly, but expect rapid change with change in US human space flight plans
How do I reach this market?	internet, technical conferences, personal email;
How do competitors reach this market?	no competitors
What do customers expect for this product?	a proven system with clearly defined requirements
What core competencies must product have?	operate in space environment with wide range of thermal conditions
What are customers willing to pay? 1) hardware 2) FMS simulator 3) FMS Consulting	 not yet established. The 1980's failed NASA one cost $4 million net yet established - possibly $80,000 per unit probably < $50,000 per contract
What is my competitive advantage?	will be the only one to meet requirements; simulation of capabilities will be available free on-line, in advance

The key commercial risk is in unit pricing. Though we anticipate being the sole supplier, the cost of the technology may delay its implementation into the systems which it will support.

4.0. Benefits to Canada

4.1 Technological innovation

The challenge of solving the space robotic force moment sensor is significant, in spite of the fact that it's a product that is at least a decade overdue.

Google on 'space robotic force moment sensor' and there's lots of information of interest to Canada, on the first page. Our FMS concept paper is the 2nd hit down. The first hit on the page is by someone at CSA who is discussing a force moment accommodation approach - which needs a FMS (he's not interested in the FMS development - only in its use - we've spoken). The 6th hit, is a quote from MDA about Dextere - and that the most important thing about Dextre is FMS. Here's the quote:

"Probably the most important thing in Dextre is what we call the force moment sensor," explains Richard Rembala from MacDonald, Dettwiler and Associates, the renowned Canadian robotics company that has led the development of Dextre. "The sensor is located at the wrist on each arm, and this sensor really gives Dextre a sense of touch. As it's grabbing boxes, it can actually measure how hard it's pushing, how hard it's twisting. This means it can limit the forces applied to structures so it doesn't break them."

4.2 Social and economic benefits

The project we're proposing is fairly small, so the direct employment effect is small - but that employment will be long term. It is a product that will always need engineers and technicians. And it is not a product that is likely to be shipped offshore for production.

Investment returns on space products are very long term, and do not normally generate the 'hockey stick' sales curve that investors are interested in, though possibly, NASA's recent shift to private capability will change that. Either way, to continue space exploration advances, the FMS technology is one that is needed.

We are considering the use of a university research group as a means of reducing the calibration effort. It is a high cost for each unit, and it is complex. It is possible that neural networks can help to reduce the time and cost for calibration. This will be part of the calibration design task.

Our location at Downsview Park is an added benefit to Canada. Downsview Park is an eclectic neighbourhood: aircraft industry (Bombardier Plan, Toronto Aerospace Museum, Helicopter pad for Global TV, Downsview Military Air Base), economic and social challenges (high crime neighbourhood, Sunrise Propane Explosion, social housing center) and strong university presence. When we employ people - some of them will be new grad's from the local university and some of them will require less education. Projects with highly visible high tech prestige make all of us proud. Those we employ locally will be inspired to be working ‘at the top of the world’. These are all goals that please potential funding agencies - both private and government.

5.0 Loan Repayment

GVE expects to begin receiving revenue from FMS unit sales in 2015. We propose to ramp up our repayment over 3 years to a level amount thereafter for a total repayment period of 15 years, beginning with $50,000 at the end of 2016, levelling out annually.