BOMEM

NGST

Next Generation Space Telescope

Final Report

Volume 1 - Executive Summary

Document Number:	**SP-BOM-005/99**		
Issue:	**1**	**Revision:**	B
Issue Date:	**13 October 1999**	**Document Name:**	Annex B1.doc

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DOCUMENT CHANGE RECORD

Issue	Rev.	Date	Chapter/Paragraph Number, Change Description (and Reasons)
1	-	30 March 1999	First release of document
1	A	20 August 1999	New revision to remove references to cost, for inclusion with final report to NASA
1	B	13 October 1999	New revision to remove proprietary notices.

1. INTRODUCTION

The Next Generation of Space Telescope (NGST) project of NASA is intended to provide continuity and new focus for research following the success of the Hubble Space Telescope. It is considered to be a technologically challenging project as the technology needed is not necessarily available. It challenges the innovation of the scientific and technological community to come up with an affordable technology to carry out the scientific goals of the mission.

Canada has a strong astronomical community and they have ranked the participation of this project as the priority in their LTSP III submission. In order for Canada to participate, the areas of technical expertise and competence necessarily has to match the required technologies of the NGST project.

At the end of 1998, CSA awarded a number of contracts to Canadian firms in order to define the nature and scope of the potential Canadian contribution to NGST. Bomem was awarded a contract (9F007-8-3007/001/SR) to study the potential use of a Fourier Transform Imaging Spectrometer as a science instrument for NGST. Bomem has been building Fourier Transform spectrometers for more than 25 years and has several thousands commercial units installed world-wide. Very early, Bomem also established itself as a world leader of advanced IR instrumentation, developing state-of-the-art spectrometers for balloon-borne, aircraft as well as spacecraft. Today Bomem is involved in several major space Fourier Transform programs, including the ESA MIPAS, CNES IASI, NPOESS CrIS and JPL TES programs, to name a few.

The purpose of this document is to summarise the results from the CSA funded NGST study. This document is Volume 1 – *the Executive Summary* - of the final report. The other deliverables of the study contract are listed in Table 1.

Table 1: Deliverables of the study contract

Volume	Document Number	Document	Description
1	SP-BOM-005/99	Executive Summary	5-page summary of the findings of the contract
2	SP-BOM-006/99	Planning Report	Report on the scheduling and cost of the proposed Canadian participation. The planning report also includes the risk assessment and mitigation plan
3	SP-BOM-007/99	Trade Analyses	Report on the trade analyses performed to arrive at a credible baseline for the proposed Canadian participation.
4	SP-BOM-008/99	Performance Analyses	Report on the sensitivity analyses performed to evaluate the suitability of the proposed Canadian participation for NGST
5	SP-BOM-009/99	Technology Report	Report on some proposed novel technology approaches to the specific NGST environment for the proposed Canadian participation.

Bomem is currently conducting a follow-on contract (9F007-8-1136/001/SR) to build a prototype interferometer to study key technological challenges identified in the first study. The documents listed in Table 1 and the test results from the prototype will be included in the Canadian Imaging Fourier Transform Spectrometer final report, due 1 October 1999.

1.1 REFERENCE DOCUMENTS

RD 1 Bomem Proposal No:SPIR180898, issue 1, revision -, dated 8 September 1998, in response to solicitation No 9F007-8-3007/A.

RD 2 Volume 2 - Planning Report, SP-BOM-006/99

RD 3 Volume 3 - Trade Analyses, SP-BOM-007/99

RD 4 Volume 4 - Performance Analyses, SP-BOM-008/99

RD 5 Volume 5 - Technology Report, SP-BOM-009/99

2. SUMMARY OF THE STUDY CONTRACT

Figure 1 shows the structure of the study contract as it was presented in the Bomem proposal (RD 1). This work flow was followed closely during the execution of the project. The labels on the left hand side of the boxes in Figure 1 refer to the items requested by the government in Section 2 of the statement of work. As can be seen a number of additional tasks were added to complement and enhance the suggested work.

In the task "Explore IFTS trade space", we explored the trade space of the NGST IFTS to arrive at a technical baseline. The results of the trade studies are described in Volume 3 (RD 3) and summarised in Section 3. This technical baseline raises the fundamental design issues on one hand and proposes a baseline with a representative level of complexity of the final instrument on the other, with enough details to be able to build a realistic cost and schedule estimate.

The spectrometric performance of this baseline was evaluated to verify compliance with the science requirements. The results from the simulations can be found in Volume 4 (RD 4). The IFTS technology was found to not only to satisfy the scientist requirements but also to enable more science because of the wealth of information conveyed by this type of integral field system.

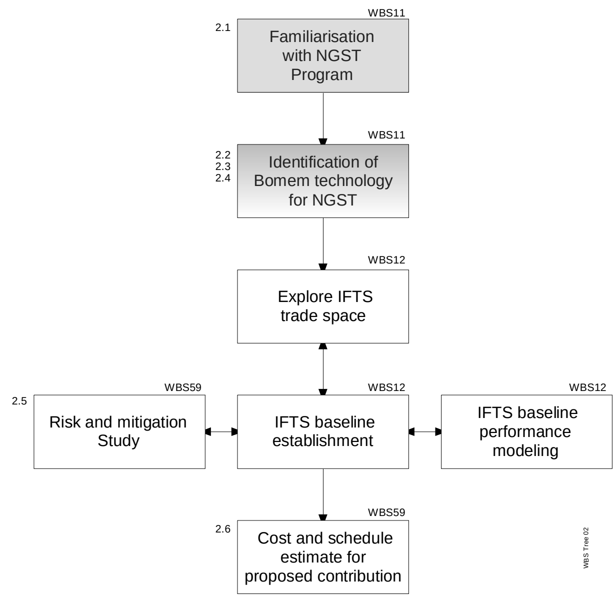

Figure 1 Structure of the Bomem lead study contract.

After completing the technical investigations, a risk analysis was performed and a mitigation plan was drafted as reported in Volume 2 (RD 2) and are summarised in Section 4. The cost and schedule estimates were produced and are described in the same volume and are summarised in Sections 5 and 6.

3. PROPOSED PARTICIPATION

The proposed Bomem participation in NGST is the interferometer subsystem of an Imaging Fourier Transform Spectrometer (IFTS) for NGST. Given the very broad wavelength range of NGST, it is believed that the subsystem will actually be composed of three separate interferometer modules and one dichroic module to steer the light into them. **This constitutes the baseline for the schedule and cost estimates presented in this report**.

The interferometer modules are defined as complete subsystems capable of operating by themselves. The subsystem includes the opto-mechanical components (mirrors, beamsplitters and possibly collimating and condensing lenses or mirrors, depending on the primeship of these items) interferometer structural and thermal control assemblies, metrology assembly (metrology source, optics, detector and electronics) and interferometer control electronics. Figure 2 illustrates these components.

We propose a development approach that uses basically three key models, 1) a breadboard which is currently under development, 2) an engineering model which will be form, fit and function compatible with the flight model but may use lower grade of space qualification on the electronics, and 3) a flight model.

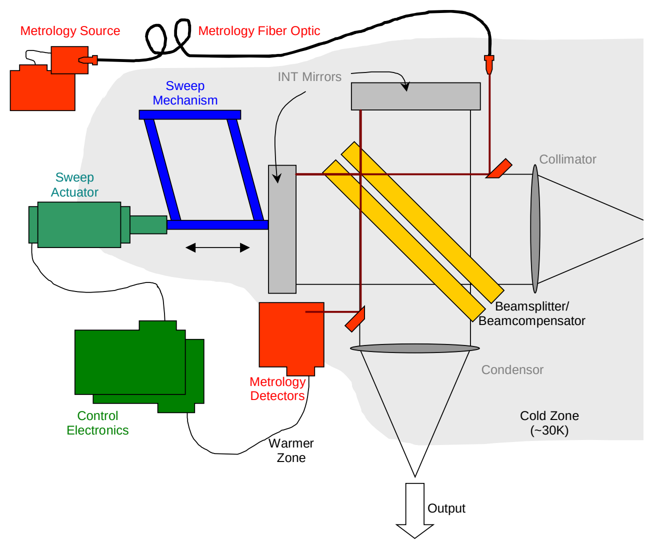

Figure 2 Schematic of NGST IFTS Components

4. RISK ANALYSIS AND MITIGATION PLAN

The risk associated with the proposed development was analyzed using a standard method proposed by DSMC (Defense Systems Management College, www.dsmc.dsm.mil). The method was used on other Bomem/ITT projects as a relative risk assessment method. It analyze the probability of development failure by looking at 3 different causes of failure and evaluate the importance of three type of consequences in case of failure. By selecting the appropriate weighting factors between each item, one can evaluate the overall risk. The formulae used to calculate the final risk factor are given in RD 2. The table shall be used to compare each component and to assess the risk mitigation priority.

Table 2: NGST IFTS Risk Factor

Risk No.	Item \ Weighting Factors	Maturity (Pm) a 0.33	Complexity (Pc) b 0.34	Dependency (Pd) c 0.33	Probability of Occurrence (Pf) Pf = a Pm + b Pc + c Pd	Technical Factor (Ct) d 0.3	Cost Factor (Cc) e 0.15	Schedule Factor (Cs) f 0.55	Consequence (Cost of Occurrence) (Cf) Cf = d Ct + e Cc + f Cs	Total Risk (Rf) Rf = Pf + Cf - (Pf * Cf)
1	Metrology Source qualification	0.3	0.1	0.5	**0.30**	0.5	0.7	0.9	**0.75**	**0.825**
2	Cryogenic Metrology Fiber Optic Qualification	0.3	0.1	0.5	**0.30**	0.5	0.2	0.5	**0.46**	**0.617**
3	Metrology Detector qualification	0.1	0.3	0.2	**0.20**	0.5	0.3	0.5	**0.47**	**0.577**
4	Sweep actuator performance	0.8	0.5	0.5	**0.60**	0.7	0.5	0.9	**0.78**	**0.912**
5	Sweep Mechanism performance	0.5	0.5	0.3	**0.43**	0.7	0.2	0.3	**0.41**	**0.663**
6	Sweep technique performance (step scan)	0.9	0.7	0.3	**0.63**	0.5	0.3	0.5	**0.47**	**0.806**
7	Dynamic alignment performance	0.9	0.7	0.3	**0.63**	0.7	0.1	0.5	**0.50**	**0.817**
8	Dicroic system qualification	0.3	0.3	0.5	**0.37**	0.7	0.5	0.7	**0.67**	**0.791**
9	Interferometer beamsplitter qualification	0.3	0.1	0.5	**0.30**	0.7	0.4	0.3	**0.44**	**0.603**
10	Mirror qualification	0.1	0.1	0.5	**0.23**	0.5	0.3	0.3	**0.36**	**0.508**
11	input/output optics qualification	0.1	0.1	0.5	**0.23**	0.7	0.3	0.5	**0.53**	**0.639**
12	Control electronics qualification	0.3	0.5	0.5	**0.43**	0.7	0.5	0.5	**0.56**	**0.751**
13	Calibration source performance	0.9	0.8	0.3	**0.67**	0.3	0.5	0.5	**0.44**	**0.814**
14	Control software & algorithm performance	0.7	0.5	0.2	**0.47**	0.7	0.3	0.8	**0.70**	**0.837**

The summary of the analysis for the development of an interferometer subsystem for the NGST IFTS is given in Table 2. The three most important risk elements are found to be: 1) the sweep actuator performance, 2) the control algorithms and software and 3) the metrology source qualification. Table 3 presents the result of the risk analysis and drafts a mitigation plan. A part of the mitigation plan is currently underway with the breadboard contract (pre-phase A activities). This will give Bomem the ability to validate some of the technology planned for the interferometer. In fact the breadboard tests will address some of the crucial aspects of risk # 4, 5, 6, 7, and 15 which include the two top risk elements. For items # 1, 3 and 10 to 13, space qualification has already been performed on similar components on previous space instruments.

Table 3: NGST IFTS Risk Factor and Mitigation

No.	Level	Risk Identified	Risk Mitigation planned during phase A
1	**0.825**	**Metrology Source qualification**	Assess requalification of diodes from programs with less stringent PA requirements.
2	0.617	Cryogenic Metrology Fiber Optic Qualification	Perform transmission and polarization tests at cryo temperatures
3	0.577	Metrology Detector qualification	Assess requalification of diodes from programs with less stringent PA requirements.
4	**0.912**	**Sweep actuator performance**	Perform testing on current breadboard prior to instrument design and select alternate technologies if necessary
5	0.663	Sweep Mechanism performance	Study several designs and run test on current breadboard
6	0.806	Sweep technique performance (step scan)	Perform extended testing on breadboard version
7	0.817	Dynamic alignment performance	Perform alignment by iterative optimization techniques
8	0.791	Dicroic system qualification	Research past cryogenic programs for mirror performance
9	0.603	Interferometer beamsplitter qualification	Research past cryogenic programs for mirror performance
10	0.508	Mirror qualification	Research past cryogenic programs for mirror performance
12	0.639	input/output optics qualification	Research past cryogenic programs for mirror performance
13	0.751	Control electronics qualification	Select space qualified components
14	0.814	Calibration source performance	Perform extended study and simulation of various approaches
15	**0.837**	**Control software & algorithm performance**	Test uncompiled high level version on breadboard.

5. PROPOSED COST

The cost estimate was built using a bottom-up methodology. The work breakdown was first constructed using a classic project model composed of two models (engineering model and flight model) and the usual development cycles bounded by the kickoff, PDR, CDR and TRR milestones. Next a detail work form was filled out for every task. This level of detail is sufficient to produce a realistic and solid cost estimate. The level of efforts were entered based on experience on similar projects and based on the work already completed and the risk analysis described in Section 4. For a detailed discussion on the methodology and cost drivers see RD 2. Table 4 shows the summary of the cost estimate for the development of the interferometer module for the NGST IFTS.

To make things clear and simple, this cost estimate covers only the IFTS interferometer subsystem. However there are a number of other subsystems or components that Bomem is interested in developing and for which Bomem possesses a unique, world-class expertise. Table 5 lists the three main areas where Bomem could also contribute, along with rough-order-magnitude cost estimates. Bomem would be pleased to present the relevant capabilities and past experience and to hold discussions with CSA on these additional developments.

Table 4: Cost estimate summary

TABLE REMOVED

Table 5: Cost estimates for items not part of the proposed contribution

TABLE REMOVED

6. SCHEDULE

A schedule was constructed around the four milestones provided by CSA, namely the NGST IFTS Kickoff, FM PDR, FM CDR and delivery. The resulting schedule was found to be quite aggressive and is thought to increase the risk of the development, considering that a large team (>25) has to be built in a very short time. The work performed on the breadboard (pre-phase A) will help quickly come to a technological baseline for the EM, but the proposed schedule is still considered to be restrictive. Bomem would recommend to increase the timeframe by 20-40% if it is possible, by example starting the EM program earlier, even at a reduced effort.

7. CONCLUSION

The work performed under this study contract clearly identifies an exciting Canadian involvement in the NGST program, the development the heart of the NGST IFTS. We found that the technology has enormous science returns and could be developed completely in Canada for less than [**COST INFORMATION REMOVED**]. This cost was found to be compatible with the development of similar space instruments. The risk identified are relatively low considering the sophistication of the NGST mission, partly due to the expertise and solutions put forward by Bomem.

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