

917

SBS, SMART &

### Smart proposal advice

Reference	1939
Applicant	Satellite Propulsion Research Ltd
Project Title	Development of a Microeng for Sat Propulsion
Advice Required From	Imperial College London - Dept of Electrical and Electronic Engineering
Type of Project	Development
Date advised by	24 July 2003

### LEVEL OF TECHNOLOGICAL INNOVATION

[Is the proposed work likely to lead to a technological advance over existing products or processes? Does the end deliverable meet the purpose of this scheme element (that is, is the work more experimental research than straightforward 'development' or vice versa? Does the work have any 'strategic importance' for industry in England?]

The work proposed is likely to lead to a technological advance over existing products. However, the work is more experimental research in nature, as there are real practical problems that need to be addressed in order to implement a working demonstrator. If successful, the UK would lead in this technology and so this high profile application is strategically important.

Please rate the level of technological innovation | High |  Medium |  Low |

### TECHNICAL RISKS

[Does the work involve technical risks that need to be overcome by R&D? Does it appear that the applicant has accounted for the risks? Does the applicant have a clear method of countering these risks?]

There are many risks that need to be overcome by R&D. The applicant has highlighted most, but not all, of these. Counter measures have not been fully described in the proposal.

Please rate the level of technical risk | High |  Medium |  Low |

COMMERCIAL POTENTIAL/MARKET NEED/EXPLOITATION ROUTE

[Is there a market need for the work? Will people buy it? Is the exploitation route realistic (that is, has the applicant considered a realistic means of exploiting the results?)]

There is a market for this product, but it is not large and it may not be bought unless significant advances can be demonstrated.

Please rate the level of market potential High  Medium  Low

ENVIRONMENTAL IMPACT

[What will the wider effect of take-up be (that is, the effect on the natural and social environments, environmental sustainability, health and safety and so on).]

This proposal has very little environmental impact

Please rate the level of positive environmental impact High  Medium  Low

DESIGN IMPACT

[What will the impact be on design (if any)? Does the project incorporate good design principles and/or enhances design capabilities. Or is design is not considered important?]

Design impact is not so important, in terms of aesthetics, however, it can make considerable savings when compared to the cost of alternative designs

Please rate the level of design impact High  Medium  Low

DO YOU KNOW THE APPLICANT? Yes  No

[If "Yes" please include what capacity you know the applicant in and take a view on the competence of the applicant to carry out the project in your comments below.]

Commercial in Confidence

By seeing the given information would you recommend supporting or rejecting the project?

SUPPORT	<input checked="" type="checkbox"/>
REJECT	<input type="checkbox"/>

[Please provide a general conclusion to support your recommendation. If you recommend rejection, please clearly list the reasons for rejection (N.B. we need sufficient reasoning behind rejections).]

*Please see associated report attached.*

PLEASE INDICATE YOUR KNOWLEDGE OR EXPERTISE IN THE SUBJECT AREA

- Recognised world/national/sector expert or practitioner
- Over 5 years practical knowledge of the subject area
- Less than 5 years practical knowledge
- No practical knowledge of the subject, but some policy or related knowledge
- New to the subject area with limited or no knowledge. If you have ticked this category can you suggest an alternative source, if possible:

.....

.....

.....

NAME OF PERSON WHO COMPLETED THE FORM

DIRECTOR'S ESTABLISHMENT

DIRECT TELEPHONE NO

PLEASE RETURN TO

IMPERIAL COLLEGE LONDON

E Mail: [REDACTED]

Address: Small Business Service, Berkeley House  
Cross Lanes  
Guildford  
GU1 1YA  
Direct Line: 01483 470126  
Fax: [REDACTED]


SBS, SMART 88

17 JUL 2003

ENTERPRISE

**Review of  
"Proposal for a SMART award to support the development  
of a microwave engine for satellite propulsion"**

For

  
SMART Awards  
SBS Regional Team  
Berkeley House (Seeda HQ)  
Cross Lanes  
Guildford  
Surrey, GU1 1YA

On

16<sup>th</sup> July 2003

## Introduction

This document represents a review of the "Proposal for a SMART award to support the development of a microwave engine for satellite propulsion". It is assumed that the physical principles exploited by this invention are correctly understood. Only the technical implementation aspects of the proposal were examined.

## Points of concern

1. Section 2.6 "...help convince the space industry that a further development of the technology will lead to significant improvements in space capability." But this should have already been achieved with the "...successful completion of the SMART feasibility study ref. 931", as stated in Section 1.
2. Section 2.8 Seven milestones are given over a three-year period. The timeline seems rather long for the manufacture and test of a Demonstration Model that is based on the previous experimental thrusters on beam balance with load cell design. Two years would seem more appropriate, especially as there will be many off-the-shelf components used.
3. Section 3.1 "Attached to the centre section are alternative large and small sections which may incorporate tuning plates of dielectric sections". If dielectric sections are employed then the quality (Q)-factor of the associated cavity resonator will be severely reduced. Moreover, wherever there is a vacuum-dielectric interface, there must be a wave impedance mismatch at this boundary unless the dielectric's relative permittivity and relative permeability are equal in value. This condition would be very difficult to meet in practice. The characteristic impedance can be made continuous if proper geometrical discontinuities are introduced.
4. Section 3.5 Thrust is directly proportional to the Q-factor of the cavity resonator. As pointed out in the Conclusions Section within the "Technical Report on the Experimental Microwave Thruster", "When not correctly tuned the thrusters gave reduced thrust or no measurable thrust". This is a very serious practical consideration that must be addressed.
5. Section 3.5 "...the Q will be maximised at the proposed operating frequency (most probably 2540 MHz)". As used in the SMART feasibility study ref. 931, 2450 MHz is a much better choice of operating frequency, as this corresponds to the unlicensed ISM band and very cheap high power microwave oven magnetrons can be employed.
6. Section 3.7 (Section 3.2, SMART feasibility study ref. 931) "The overall geometry was defined by building a mathematical model of the thrusters based on an Excel spreadsheet". This approach is overly simplistic when one wishes to design cavity resonators have Q- factors approaching 50,000. In practice, full-wave 3-D numerical electromagnetic modelling software is strongly recommended. This is even more important when there are physical and electrical discontinuities associated the cavity and its peripheral microwave hardware. However, no mention has been made of purchasing this rather expensive validation software and critical design tool.

*Some work was not done but this is a long term work item. The closed section can be done. This has some of us off and may be going on and allows for shopping.*

7. Section 3.7 "Successful high power operation at high Q will also be dependent on suppressing arc discharges". Multipaction would be a serious problem in a space environment, but this has not really been addressed.
8. Section 3.7 Power dissipated inside the resonant cavity, due to joule heating, will cause a significant temperature rise and, as a result, thermal expansion. This, in turn could cause serious detuning of the high Q cavity resonator. This has not been addressed.
9. Section 3.7 Magnetrons are notoriously noisy and unstable, in terms of frequency drift and output power level, both as a function of time and temperature. Employing high Q-factor resonators will result in a practical limit on the ability to implement impedance tuning. It would be more appropriate to replace the Magnetron with a solid-state medium power oscillator/power amplifier chain.
10. Section 3.7 When creating such small levels of mean thrust (~ 2g), it is very important to employ the services of an accredited independent test house (e.g. National Physical Laboratory) to verify measurements, especially if there is any doubt about the theory or experimental set-up associated with this technology. Spurious effects due to cooling fan operation and outgassing of cooling air from the thrusters have been ruled out by SPR Ltd only.
11. Section 4, as with technical results produced for the SMART feasibility study ref. 931, colours are not easily represented in black and white photocopied documents. The figures are difficult to interpret.
12. Section 5 "The high thrust available from these engines would have an enormous potential for use in ground and airborne transportation". There is absolutely no evidence to support this statement, quite the contrary in fact.
13. Section 5 "The basic technologies of power supply, magnetron and thrusters are each readily capable of space qualification". However, magnetrons are not space qualified, as pointed out in the Review of "Technical Report on the Experimental Microwave Thruster" (Section 4.3).
14. Section 9 "There has been a universal appreciation of the possible high commercial return, but a disappointing level of understanding of the technical detail". This theoretical base for this invention has still to be validated. Moreover, the feasibility of a practical implementation needs much more work.
15. Annex F In addition to point 3, a UK travel budget of £3,600 is excessive and difficult to justify.

### Conclusions and Recommendations

The SMART Award proposal represents a bid to take blue skies research one step closer to the commercial space environment. There is still some reservation as to the theoretical validity that underpins the basic ideas. This could be seen as reminiscent of the flawed work undertaken by the late Professor Eric Laithwaite on perpetual motion for space travel using gyroscopes. However, should the theory be proved correct, there are still many practical issues that have to be addressed, in order to demonstrate a working thruster for space applications. Based on all the documentation supplied, it is recommended that funding should be made available under the SMART Award scheme to develop a working Demonstration Model. However, the points raised within this review should be addressed by the applicant to the satisfaction of the funding body.

Questions raised by the funding body:

1. *Is the proposed work feasible (will it work)?* **This remains to be seen, but preliminary results suggest it could work.**
2. *Is the proposed work a technological advance leading to an innovative or novel product or process?* **Yes, without question.**
3. *Does the work involve technical risks that require research and development work?* **Most definitely.**
4. *Is there a market need for the work?* **The market exists, but it is very small.**
5. *Does the proposed exploitation route appear to be realistic?* **Yes, in general.**