REPORT

ON

OPPORTUNITIES FOR

MICROGRAVITY RESEARCH

Prepared for

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1. Introduction

This report is submitted in fulfilment of Part I of the requirements of SSC Contract No. 31016-0-6019/02-SW entitled "The Identification of Opportunities for Microgravity Research and the Evaluation of the Rocket and Small Satellite Programs". The results will contribute to the long term plan for space science.

2. Study Objectives

The study objectives were to

a) review responses already solicited from the scientific community outlining proposals for experimentation in microgravity;

b) determine what additional information is needed and obtain this information; and

c) prepare a document synthesizing the findings for consideration by the Advisory Committees to the Space Science Program.

3. Methodology

The Canadian Space Agency received about 200 replies to a widely distributed questionnaire soliciting proposals for experimentation in microgravity. CSA screened the replies and placed them into one of four categories:

- life sciences proposals from new potential participants;
- materials sciences proposals from new potential participants;
- responses from current participants; and
- replies deemed non-responsive due to inadequate information.

We reviewed replies dealing with new potential participants in life sciences and materials science, and in consultation with the scientific authority, developed a further questionnaire requesting information on infrastructure requirements to support proposals. CSA mailed this second questionnaire to those who provided qualified proposals in the fields of life sciences and materials science. Replies to this questionnaire were followed-up by telephone to obtain as complete a set of data as possible.

We prepared summary sheets containing basic information on each proposal and the infrastructure requirements received from new potential participants. The form of presentation was discussed with the scientific authority who considered it suitable for use by the appropriate advisory committees.

4. Results

4.1 Life Sciences

Sixty five life sciences responses were considered valid. We have classified these into the following categories:

- Basic Science (5);
- Plants and Food (10);
- Molecular Biology (6);
- Neurology (12);
- Skeletal Muscles and Bones (16); and
- Physiology (17).

The numbers in brackets show the responses in each category.

Thirty two replies provided sufficient information to make the following assessment of the vehicle required to accommodate the proposed experiment.

Vehicle	Number of Users
Space Station	26
Satellite	3
KC-135	2
Rocket	1

The results for life sciences are presented in spreadsheet form in Appendix I.

4.2 Material Science

There were 29 material science replies. We placed these in the following categories, with numbers in brackets showing responses:

- Metals/Alloys (5);
- Ceramics/Glasses (2);
- Semiconductor Studies (6);
- Liquids/Catalysts (5);
- Heat Flow/Transfer (7); and
- Structure/Damage (4).

Of the 29 replies, 20 provided sufficient information to assess the vehicle required. Based on stated requirements/wants the findings can be summarized as follows:

Vehicle	Number of Users
KC-135/T-33	6
Satellite	5
Space Station	4
Rocket	5

Appendix II contains spreadsheets for materials science.

In order to provide a complete picture, we have summarized the contracts reported in Microgravity Program Update Number 4, May 1990, and from information provided by the client on the current contracts. These summaries are contained in Appendix III.

5. Conclusions

In addition to our summaries, we offer the following observations.

5.1 Life Sciences

Space Station is the vehicle of choice for most of the experiments where sufficient information was given to provide a basis for judgement. It would accommodate 26 out of the 30 assessed.

The clustering of interests expressed by responses in the questionnaires suggests there are opportunities to form teams from among the potential participants. If it is not possible or feasible to form teams, then at least those in the groups noted below should be aware of the allied interests.

Subject	Interested Responders
Gravitational effects on plant growth	M.A. Dixon (Guelph U.) R.F. Horton (Guelph U.)
Nitrogen fixation in reduced gravity	D.B. Layzell (Queen's U.) D.L.Smith (MacDonald College, McGill)
Visual and vestibular systems	F.O. Black (Portland. Ore.) M.S. Cynader (UBC) A. Friedman (U of A, Edmonton) L.R. Harris (York U.)
Human motor control system	O. Bock (York U.) C. MacKenzie (U. of Waterloo)
Exercise and skeletal muscle atrophy	M.J. Plyley (U of T) W. Rhodes (Willowdale, Ont) (already collaborating)
Bone formation and calcium deposition	P. Brazeau (U. Montreal) M.D. Grynpas (Mt. Sinai, Toronto)
Muscles and exercising in space	W. Herzog (U of Calgary) J.G. Reid (Queen's) C. Frank & N. Shrive (U of Calgary)
Respiratory system	E. Dean (Vancouver) J. Edelson (St. Michael's) D.C.F. Muir (McMaster U) T. Trippenbach (McGill)
Sleep & sleep disorders	M. Kryger (U of Manitoba) H. Moldofsky (U of T)
Cardiovascular system	R.L. Hughson (U of Waterloo) R. Thirsk (CSA)

5.2 Material Science

The range of vehicles required to satisfy experimental conditions is broader than is the case for life sciences investigations. Although there are preferences, all vehicles have been identified at least twice. The KC-135/T-33 and satellites together would meet about half the projected needs.

About one half of the suggested subjects deal directly with experiments on materials processing/behaviour in microgravity. The remainder involve topics related generally to instrumentation, techniques or theoretical studies.

About one third of the proposed investigations require a furnace. There are therefore opportunities to link these investigators with UDP contractors who have developed furnaces.

Some potential investigators expressed a desire to collaborate with PI's who have experience working in microgravity. These are

1. Dr. H. Henein, University of Alberta;
2. Mr. Miroslav Grmela, Ecole Polytechnique;
3. Mr. S.V. Hoa, Concordia University; and
4. Prof. G. Papini, University of Regina.

6. Acknowledgements

We wish to acknowledge the support received from a number of people in the Space Sciences Division of the Canadian Space Agency. Immediate response to requests for information together with constructive feedback has allowed our assignment to progress efficiently.

Appendix I
Life Science Summary

NOTE: a * indicates infrastructure required.

Basic Science Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
1. Prof. Peter G. Kevan Dr. Franco Di-Giovanni Department of Environmental Biol U. of Guelph Guelph, Ontario N1G 2W1 Bus. (519) 824-4120 Res. (519) 658-0573	Biophysical Ecology	Test dispersal models for pollen, aerosols, particles in microgravity environment and compare with earthbound experiments to confirm and possibly modify the effect of gravitation on the models.	minutes*	<.0001*	data rec* video *		Requires a pollen-free atmosphere. Continuous release of pollen in wind for at least 5 minutes.
2. Prof. Locksley E. McGann Dept. of Pathology U. of Alberta Edmonton, Alberta T6G 2R7 Bus. (403) 431-0202 Res. (403) 962-5636	Cryobiology for Prolonged Space Fl	Studies on tissue banking in a microgravity environment. Expertise on low-temperature preservation of cells will be applied to preservation of blood, bone marrow and skin cells under microgravity conditions. Need to invesigate effect of microgravity on osmotic responses of cells					
3. Dr. Anthony P. Russell Dept. of Biol. Sci. U. of Calgary 2500 University Dr., NW Calgary, Alta T2N 1N4 Bus. (403)220-5198 Res. (403)272-3886	Adhesive Systems	Lizards adhere to smooth surfaces by the microorientation of epidermal keratinous outgrowths on the surfaces of their toes. The study proposes to determine the effect of gravity on this system of adhesion.	hr/days* long *	.5-.01*	cont sys data rec video * atm cont* thermal * special		Free locomotion of animals and videotaping thereof required.
4. Prof. John M. Stewart Dept. of Chemistry Mount Allison University Sackville, NB E0A 3C0 Bus. (506) 364-2361 Res. (506) 364-4327	Intracellular Diffusion	While effect of microgravity in diffusion of small molecules may be insignificant, most of the supramolecular machinery of the cell may be large enough in mass and volume to show such effects. A model system has been developed to measure diffusion coefficients and diffusional fluxes from muscle tissues. Studies would extent measurements to microgravity conditions.	hr/days* long *	.0001 *	cont sys thermal *		
5. Prof. Peter G. Wells Faculty of Pharmacy U. of Toronto 19 Russell Street Toronto, Ont M5S 2S2 Bus. (416) 978-3221 Res.	Drug and Toxicity	Models of drug-induced disease, particularly in areas of liver disease, birth defects, and cancer, would be used to determine modulatory effects of microgravity on drug toxicity and, if evident, the underlying biochemical mechanisms. Possible relevance to health of astronauts.					

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Plants and Foods Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
6. Prof. S. Cenkowski Dept. of Agric. Engineering U. of Manitoba Winnipeg, Man R3T 2N2 Bus. (204) 474-6033 Res. (204)	Agricultural and Food Engineering	Engineering of systems for environmentally controlled plant production under reduced gravity. Processing of plant products into food requires further knowledge about effects of microgravity on the flow-behaviour of fluid-solid mixtures.					
7. Dr. Mike Dixon Dept. of Horticultural Sci. U. of Guelph Guelph, Ont. N1G 2W1 Bus. (519) 824-4120-2555 Res. (519) 824-4196	Gardens in Space	Studies on the influence of zero or reduced gravity on water and carbohydrate transport systems in plants, geotropic influences and biophysical mechanisms. Use of a technique to continuously monitor the water status of a plant would allow evaluation of potential culture of plant species in microgravity.					
8. Prof. Mario Julio Fragata Centre de recherche en photobiophysique U. de Quebec a Trois Rivieres Trois-Rivieres, Que G9A 5H7 Bus. (819) 376-5077 Res. (819) 379-0856	Photosynthesis	Proposes studies on adhesion of chloroplast thylakoids involved in energy distribution in photosynthesis. Will determine effects of mono and divalent cations on lipid vesicles interactions in microgravity. Will study the mechanisms underlying the lack of reversible adhesion of thylakoid membranes in vivo in microgravity.					
9. Dr. Roger F. Horton Dept. of Botany U. of Guelph Guelph, Ont. N1G 2W1 Bus. (519) 824-2656 Res. (519) 821-0975	Plant Growth	Have studied processes controlling plant growth under environmental changes, e.g. aquatic, semi-aquatic and anaerobic conditions. In anaerobic conditions rice retains its ability to repond to gravity vector. Continuing studies of gravitational effects, often using mutants.					
10. Prof. Robert Kok Agricultural Engineering MacDonald College McGill U. 21,111 Lakeshore Blvd. Terrasse Vaudreuil, Que H9X 1C0 Bus. (514) 398-7781 Res. (514)	Life Support Systems	Development of artificial intelligence systems oriented towards productive ecological system management, operation and regulation. Investigation of uses of insects for food, feed, biomaterials, waste processing. Insects as components of life-support systems in space.	long *	level not critic.	atm cont thermal special handling		

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Plants and Foods cont'd Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
11. Prof. David B. Layzell Biol. Dept. Queen's University Kingston, Ont K7L 3N6 Bus. (613) 545-6149 Res. (613) 546-0576	Nitrogen Fixation	Growth of nitrogen-fixing plants (legumes) in microgravity will probably be necessary on prolonged space flights. Important factor limiting nitrogen-fixation is oxygen diffusion, controlled by legume nodules, by physiological control of water and air space distribution in nodule tissue. Propose to see how this control is affected by microgravity conditions.	long *	.5-.01* .0001	cont sys* atm cont* thermal * special handling		
12. Mr. Michele Normore Dept. of Biol. Memorial U. of Nfld St. John's, Nfld A1B 3X9 Bus. (709) 737-4339 Res. (709) 368-2926	Plant Growth	Studies of light (wave length, intensity) efforts on auxin concentrations. Would like to add a study of gravitational variation to these. Aimed at long-term growth of plants in gravity-free environment.					
13. Dr. Richard P. Pharis Biol. Sci U. of Calgary Calgary, Alta T2N 1N4 Bus. (403) 220-5259 Res. (403) 932-2124	Giberellins in Plant Growth	Propose to examine endogeneus gibberellin concentrations in shuttle-grown maize plants. Concentrations of all plant hormones involved in the gravi-response system will be determined by gas chromatography-mass spectrometry.					
14. Dr. Rod Savidge Dept. of Forest Resources U. of New Brunswick Fredericton, N.B. E3B 6C2 Bus. (506) 453-4501 Res. (506) 457-1733	Reactionwood Formation in Trees	Compression and tension wood are formed as a result of changes in cellular differentiation pathway and an understanding of how compression and tension wood development are regulated is important to an understanding of differentiation in general. Gravity mediates but is not obligately essential in reactionwood formation. Proposes to define the precise role of gravity.	days * long	.0001 * <.0001*	atm cont* thermal * special * other *	70 cm W * 70 cm L * 70 cm H *	Gro-lux fluorescent bulbs to provide light over a 16 hr photoperiod. carbon dioxide and oxygen required. A 2 week continuous exposure desirable.
15. Dr. Donald L. Smith Plant Sci. Dept McGill U. 21,111 Lakeshore Rd. Ste. Anne de Bellevue, PQ H9X 1C0 Bus.(514) 398-7866 Res. (514) 457-6170	Nitrogen Fixation in Provision of	Use of Nitrogen-fixing organisms on space flights will provide high protein food without necessity of carrying fertilizer. Proposes to examine the culture of two groups of organisms under microgravity conditions; cyanobacteria and legumes	long	.0001 *	sont sys atm cont thermal light special handling		

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Molecular Biology Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
16. Prof. M. Arella Inst. A. Frappier/U. de Quebec 531 Boul. des Prairies Laval Des Rapides, PQ H7N 4Z3 Bus. (514) 687-5010 x 225 or 234 Res. (514) 689-0264	Insect Viruses	Proposes to study the crystallization of insect viruses within cells. Experiments in microgravity conditions will permit verification of assembly and level of production of viral proteins and their biosynthesis within cellular systems.	hr/days*	.5-.05	cont sys data rec video * atm cont thermal * special handling		Requires 28 degree C special handling.
17. Dr. T.J. Beveridge Dept. of Microbiology U. of Guelph Guelph, Ontario N1G 2W1 Bus. (519) 824-4120 x 3366 Res.	Bacterial Surfaces	Proposes to study the effect of microgravity on the way by which bacterial surfces bind metal and participate in mineralization. Also proposes to use microgravity to produce 3-dimensional crystals of protein aggregates in bacterial cell walls for X-ray studies.	hr/days*	<.0001*	atm cont thermal		Use bacteria as centres for mineral crystal growth. One to seven days long enough.
18. Dr. Louis T.J.Delbaere U. of Saskatchewan Dept. of Biochem. Saskatoon, Sask. S7N 0W0 Bus. (306) 966-4373 Res. (306) 242-1529	Protein Crystallization	Propose to use microgravity conditions to improve crystallization of proteins for X-ray structure determination. Of particular interest are: (i) fab fragments from antibodies specific for a bacterial protein, (ii) the fab-protein complex and (iii) human blood group determinants complexed with lectin.	long *	.0001 *	thermal atm cont		
19. Prof. H.M. Dosch Hosp. for Sick Children 555 University Avenue Toronto, Ontario Bus. (416) 598-6260 Res. (416) 366-3822	Eukaryotic Cell Growth DNA Sequenc	Proposes to see if eukaryotic expression systems for recombinant biological molecules will gain in efficiency in microgravity, e.g. will contact inhibition decrease and cell density increase? Will elimination of gravity diffusion allow separation of longer DNA segments, thus making sequence studies faster, and cheaper?	long days *	.01 * .0001	cont sys data rec thermal special handling		Self-contained systems can be flown. Bench top fermentators.
20. Prof. Barry W. Glickman Biol. Dept York University 4700 Keele Street North York, Ont. M3J 1P3 Bus. (416) 736-5242 Res. (416) 739-8360	Replication Processes; DNA repair	Proposes to study the effects of microgravity on the fidelity of replicational processes. Would like to test the fidelity of replication enzymes in vitro in space and the accuracy of DNA repair processes in microgravity. Also propose a study of how microgravity affects cell survival and mutation due to ionizing radiation.					

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Molecular Biology cont'd Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
21. Prof. C.A. Lingwood Hosp. for Sick Children 555 University Avenue Toronto, Ont Bus. (416) 598-5998 Res. (416) 239-3457	Glycolipids as receptors for pathogenic bacteria	Would propose to see how microgravity affects infectivity by pathogenic bacteria - e.g. increased aerosol formation or effect on surface adhesion of bacteria. Other aspects of infertility are effects of gravity on immune system and selective effects of reduced oxygen tension.					
Neurology							
22. Dr. F.O. Black Dept. of Neuro-Otology Good Samaritan Hospital and Med. Center 1040 NW, 22nd Avenue (N010) Portland, OR, 97210 U.S.A. Bus. (503) 229-8163 Res. (503) 636-7114	Vestibular Systems	Collaboration with Dr. Robert Peterka on normal and abnormal vestibular function. Goal is to be able to predict susceptibility to motion sickness by studies of reflexes, motion perception and sensory selection abilities.					
23. Prof. O. Bock Inst. Space and Terrestrial Sci. York University 4700 Keele Street North York, Ontario M3Y 1P3 Bus. (416) 736-5659 Res. (416) 294-4548	Human Motor Control System	Will study aimed arm movements in humans under exposure to low gravity to gain insight into mechanisms of gravity compensation by human motor control system, to study mechanisms of adaptation and to design space activities that take into account the limitations of human zero-g performance.	hr/days* long	.5-.01* .0001	video		Need data downlink. Some work can be done in the KC-135.
24. Dr. Kenneth B. Campbell School of Psychology 420b Montpetit Hall University of Ottawa Ottawa, Ontario K1N 6N5 Bus. (613) 234-9019 Res. (613) 234-9019	Human Brain Information Processing	Effect of gravity on variation in circadian rhythym, vigilence, arousal, alertness and optimum levels of performance.	minutes* hr/days* long	.5-.01 .0001 <.0001	cont sys* data rec* video atm cont thermal *		Rough estimates.
25. Dr. Lincoln Chew Psychology Dept U. of Lethbridge 4401 Univesity Dr. Lethbridge, Alta T1K 3M4 Bus. (403) 329-2401 Res. (403) 381-8788	The developing nervous system in fish	Effects of gravity on developing nervous system. Would send live fish (salmon) eggs into space to evaluate effects on an embryonic vertebrate nervous system.					

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Neurology cont'd Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
26. Prof. Max S. Cynader Dept. of Opthamology U. of British Columbia 2550 Willow Street Vancouver, B.C. V5Z 3N9 Bus. (604) 875-4353 Res.	Visual and Vestibular Systems	Mechanisms by which visual and vestibular systems adapt to microgravity. Examination of the neurochemistry of prolonged exposure to microgravity. Establishment of part of brain that became active under microgravity and studies of adaptation of visual and vestibular systems.	long *	.0001	cont sys data rec animal handling		
27. Dr. Alinda Friedman Dept. of Psychology U. of Alberta Edmonton, Alta T6G 2E9 Bus. (403) 492-5216 Res.	Visual and Vestibular Systems	Cognitive psychology with emphasis on visual cognition. Results show that visual system may use data from vestibular system in making decisions about objects in different planes. Relevance to how people cope with a perceptual environment in which they have conflicting vestibular cues.	hr/days*	.0001	data rec* cont sys* video display system		Testing over periods within 4 hours possible.
28. Dr. T. Hara Dept. of Fisheries and Oceans Freshwater Inst. 501 University Crescent Winnipeg, Man R3T 2N6 Bus. (204) 983-5010 Res. (204) 488-3028	Olfactory Receptor Sites	Odor recognition depends upon interaction of low-molecular weight organic compounds with receptor cell membranes. To reach receptor site, the odorous compounds must diffuse freely through mucus layers. If odorant flow due to concentration gradient is suppressed in a reduced gravity environment, the result could be the eventual loss of the sense of smell.					
29. Mr. Lawrence R. Harris Dept. of Psychology York University North York, Ontario Bus. (416) 736-2100 x 66108 Res.	Visual and Vestibular Systems	How different senses are combined to inform the reflex and perceptual systems about head movements. Interactions between the semicircular canals and the otoliths of the vestibular system. The canals detect angular rotations of the head, otoliths detect linear accelerations, the most common of which is gravity. Studies will contribute to effects of living without gravity where otoliths are much less active.					
30. Dr. Sylvaine Lafortune Dept. of Physiology U. of Manitoba 770 Bannatyne Ave. Winnipeg, Man R3E 0W3 Bus. (204) 787-3227 Res. (204) 831-0661	Brainstem Velocity Storage Mechanism	Have shown that human, velocity storage mechanism is otolith organic dependent. Alterations in otolith organ function are thought to be involved in space motion sickness so interaction between velocity storage mechanism and otolith organ activity should also be altered in space. Significant for space adaptation.					

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Neurology cont'd Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
31. Dr. Christine MacKenzie Faculty of Applied Health Science U.of Waterloo Waterloo, Ont. N2L 3G1 Bus. (519) 885-1211 x 2612 Res. (519) 885-4493	Human Motor Control System	Goal directed human limb movements, particularly arm and hand in reaching, grasping and manipulating. Wants to examine efforts of microgravity on goal-directed aiming movements in humans.					
32. Prof. Colin MacLeod Div. of Life Sciences U. of Toronto Scarborough, Campus Scarborough, Ont M1C 1A4 Bus. (416) 287-7439 Res. (416) 698-5598	Cognitive Processes	Human attention, memory and intellectual skills are cognitive processes that may be influenced by space environment, particularly over long term. Has expertise for testing.					
33. Dr. John Woulfe Neuroanatomy Lab. Montreal Neurological Inst. 3801 University St. Montreal, PQ H3A 2B4 Bus. (514) 398-1913 Res. (514) 286-7830	Neural plasticity in space	Reduced gravity would be used to investigate aspects of neural plasticity. For example, fluid homeostasis is interrelated to blood pressure, hydrostatic pressure, hormonal regulation and neural integration. Changes in gravity would be expected to induce alterations in the physiological substrates that mediate fluid homeostasis and blood pressure.	hr/days* long		data rec atm cont* thermal * special other		Duration ambiguity related to determining the time course of the experiment. Radioactivity involved. Wants to perform experiment over a range of gravity.
Skeletal Muscles and Bones							
34. Mr. P. Fremont Dr. P.A. Rogers Laval University Hospital Research Center, S-750 2705 Blvd. Laurier Sainte-Foy, Que. G1V 4G2 Bus. (418) 654-2733 Res. (418) 527-8093 682-2146	Molecular Structure of Skeletal and Cardiac Muscle	Want to determine how sensitive the cytoskeletal structure of the muscule cell is to reduced gravity environments. Failure of the cytoskeletal system of the muscle wall to maintain its integrity may lead to atrophy.					
35. Dr. Michael J. Plyley Exercise Sciences U. of Toronto 320 Huron Street Toronto, Ont M5S 1A1 Bus. (416) 978-8563 Res. (416) 849-7796	Skeletal Muscle Atrophy	Uses hind leg suspension in rats as a model of microgravity environment. To test the effectiveness of a unilateral electrically-induced, isometric, strength training regimen in ameliorating muscle atrophy.					Collaboration with Rhodes, # 36.

NOTE: a * indicates infrastructure required.

Skeletal Muscles and Bones cont'd Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
36. Dr. Wayne Rhodes Rhodes and Assoc. Inc 177 Jenny Wren Way Willowdale, Ont. Bus. (416) 494-2816 Res. (416) 497-0276	Exercise and Depletion of Bone Minerals and Muscle Atrophy	To investigate the manner in which certain types of exercise, the frequency and length of time all contribute to reduction in bone mineral depletion and muscle atrophy. Research will be designed to determine most efficient approach.	long *	.0001 * <.0001	cont sys* data rec* video atm cont* thermal * special *		
37. Prof. Colin Anderson Dept. of Pathology U. of Western Ontario London, Ontario Bus. (519) 679-2111 x 6397 Res. (519) 652-6136	Gravitational Bone Loss	Has expertise in bone biology that could be available on a consulting basis for any project involving gravitational bone loss.					
38. Dr. P. Brazeau Center de recherche de l'hopital de Notre Deme Montreal, Que	Hormonal control of bone calcium	Has found that growth hormone or a stimulant of growth hormone have good possibilities for preventing osteoporosis under conditions of microgravity.					
39. Dr. Marc D. Grynpas Samuel Lunenfeld Res. Inst. Mount Sinai Hospital 600 University Ave. Room 984 Toronto, Ont. M5G 1X5 Bus. (416) 586-4464 Res.	Bone formation and calcium deposition	How much bone is formed and how much mineral deposited during spaceflight. Propose to supplement food pf rats in a biosatellite with stable (non-radioactive) calcium 44. Upon return bones will be analysed to determine amount of mineral deposited.	long *	.0001 *	atm cont thermal special handling (animals)		Main expense is supplement.
40. Dr. Walter Herzog Faculty of Physical Ed. U. of Calgary Calgary, Alta T2N 1N4 Bus. (403) 220-3438 Res. (403) 289-6088	Measurement of muscle forces	Have planned an acute animal experiment to test if pressures can be related to muscular forces, if this relation is location dependent in a given muscle and if the relation is specific muscle dependent.					Does not require microgravity to conduct experiments. Long term goal is to develop a theoretical model which permits quantification of individual muscle forces in human movement.

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Skeletal Muscles and Bones cont'd Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
41. Dr. David A. Hood Biol. Dept. York University 4700 Keele Street North York, Ontario M3J 1P3 Bus. (416) 736-2100 x 66640	Skeletal and Cardiac Muscles	How mammalian skeletal muscles adapt to chronic contractible activity and/or inactivity. How does cardiac muscle adapt to chronic pressure overload during growth and in adult. Looking at blood flow and mitochondrial content.	hr/days long		atm cont thermal		Space flight microgravity levels.
42. Dr. Michael I. Lindinger School of Human Biology U. of Guelph Guelph, Ontario N1G 2W1 Bus. (519) 824-4120 x 3225 Res. (519) 763-2783	Muscle ion homeostasis in Microgravity	Will follow time course of changes in muscle ion composition in the presence or absence of an exercise regimen in microgravity. Absence of full gravity is known to cause variation in blood and plasma volume and composition which in turn affect ion composition of muscles.	long *	<.0001*	atm cont* thermal * special		Any microgravity level appropriate at this time. Duration minimum 4 days.
43. Dr. J. Gavin Reid School of Physical and Health Education Queen's University Kngston, Ont. K7L 3N6 Bus. (613) 545-2666 Res. (613) 544-2306	Exercise and Module Design for Microgravity	Focus on design, construction and evaluation of exercise programs and devices for optimum maintenance of physical work in microgravity.					Does not require microgravity during initial stages. Desirable later.
44. Dr. C. Frank, Dept of Surgery Dr. N. Shrive, Dept.of Civil Eng U. of Calgary 3330 Hospital Dr. NW Calgary, Alta T2N 4N1 Bus. (403) 220-6881 Res. (403) 242-9047	Bone and Joint Atrophy	Have investigated effects of loading on maturation, healing and transplantation of bone, cartilage and ligaments. Gravity-free environment would serve as a "zero control" in which loading could be controlled more effectively.					
45. Peter Wing (Payload Developer) Lark Susak U. of British Columbia 6423 University Hospital Shaughnessy Site 4500 Oak Street Vancouver, B.C. V6H 3N1 Bus. (604) 875-2790 Res. (604) 420-3829	Spinal Changes in Microgravity	Propose to continue and expand studies scheduled for IML-1 (Back Pain in Astronauts) and IML-2 (Spinal changes in Microgravity). Includes pressure response and stereo photography of responses to isometric exercise, sinus arrythymia and ultrasound.	long *	any level	video		Station would be appropriate. Qualification testing to meet NASA requirements.

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Skeletal Muscles and Bones cont'd Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
46. Dr. Mark Tarnopolsky McMaster U. Medical Center 1200 Main Street West, Rm 3V42 Hamilton, Ont L8N 3Z5 Bus. (416) 521-2100 x 5644 Res.	Muscle protein synthesis	Studies of efficacy of dietary protein intake, and knee extension, isometric exercise upon quadricep muscle protein synthesis; experiments could be done on earth and in microgravity for comparative results.	long *	.0001	minimal req'ts		Human experiment. Dietary intake.
47. Dr. Richard Wassersug Dept. of Anatomy Dalhousie U. Halifax, NS B3H 4H7 Bus (902)494-2244 Res. (902)443-4227	Amphibian Development	Proposes to fertilize frog eggs in space and examine tadpoles (returned to earth) to assess normality. Lung development may be diminished because lungs will not play a role in buoyancy. Will compare mineralization of bones of tadpoles raised through metamorphosis in zero-g with control animals.	2 weeks	.0001	cont sys* atm cont* thermal * video light control		100-200 Lux. Minimal disturbance.
48. Dr. J.D. MacDougall Department of Physical Education & Department of Medicine McMaster University 1280 Main Street West Hamilton, Ont. L8S 4K1 Bus. (416) 525-4647 Res.	Effects of exercise on human muscle	The effects of training and detraining on structural and functional characteristics of skeletal muscle; the effects of physical activity and inactivity on bone mineralization.					
Physiology							
49. Dr. Istvan Berczi Dept. of Immunology Faculty of Medicine U. of Manitoba 795 McDermot Avenue Winnipeg, Man R3E 0W3 Bus. (204) 788-6320 Res. (204) 878-3586	Microgravity and Neurohormonal Immunoregulation	Propose that altered secretion or bioactivity of adrenocorticotropic hormone (ACTH), growth hormone (GH) and prolactin (PRL) are involved in deterioration of immune system and of hemopoiesis during weightlessness. Want to confirm by rat experiments.	long *		atm cont* special *		Effect of microgravity on the endocrine and immune systems is to be investigated.
50. Dr. Richard E. Brown Psychology Dept. Dalhousie U. Halifax, NS B3H 4J1 Bus. (902) 494-3839 Res. (902) 494-3647	Behavioral Neuroscience	Effects of microgravity on olfactory capabilities of humans and animals and on changes in ultrasonic vocalizations of animals in microgravity.					

NOTE: a * indicates infrastructure required.

Physiology cont'd Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
51. Dr. Bruce John Crawford Dept. of Anatomy 2177 Wesbrook Mall Vancouver, BC V6T 1W5 Bus. (604) 228-6568 Res. (604) 224-9110	Starfish Morphogenesis	Starfish embryos are small, simply organized and clear, making it easy to observe disturbances during development. Propose to study effects of microgravity on early morphogenesis.	long *		cont sys* atm cont* special *		Duration several days to a week. Any microgravity will suffice.
52. Dr. Elizabeth Dean School of Rehabilitation Medicine 2211 Wesbrook Mall Vancouver, BC V6T 1W5 Bus. (604) 228-7398 Res.	Cardiorespiratory System	Has been using bed rest to simulate a weightless environment and has been looking at effects on lung function and cardiac hemodynamics.					
53. Dr. Jeff Edelson St. Michael's Hospital 218 - 38 Shuter Street Toronto Ont. M5B 1A6 Bus. (416) 864-5918 Res. (416) 489-3195	Respiratory System	Has been evaluating alveolar epithelial function in the context of acute lung injury. Would be interested in small animal models, in evaluating changes in lung function, cell distribution and surfactant pool sizes in animals following exposure to microgravity.					
54. Dr. Ian P. Howard (15 collaborators) Human Performance in Space Lab 103 Farquharson Bldg. York University North York, Ontario Bus. (416) 736-5659 Res. (416) 889-0157	Human Performance	Behavioral, physiological, computational or biophysical study of sensory, sensorimotor, and perceptual systems.					
55. Prof. Richard L. Hughson Dept. of Kinesiology U. of Waterloo Waterloo, Ont. N2L 3G1 Bus. (519) 885-1211 x 2156 Res. (519) 885-1947	Cardiovascular Systems	Cardiovascular adaptations to microgravity and response to re-exposure to gravitational field. Techniques include non-invasive measurements of oxygen uptake, blood pressure, cardiac output, blood flow and analysis of blood components.	25 sec * hr/days* long *	.0001 * <.0001*	data rec*		Pilot work can be done in KC-135.

NOTE: a * indicates infrastructure required.

Physiology cont'd Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
56. Dr. K.W. Johnson Toronto General Hospital U. of Toronto 200 Elizabeth St. 9 Eaton Room 217 Toronto, Ontario M5G 2C4 Bus. (416) 340-3552 Res. (416) 221-4848	Collaboration with R. Bondar	No description supplied.					
57. Prof De Meir Kryger U. of Manitoba St. Boniface Hospital Res. Inst 451 Tache Winnipeg, Man R2H 2A6 Bus. (204) 237-2760 Res. (204) 831-1414	Sleep and Sleep Disorders	Does gravity per se have an effect on sleep? Do astronauts have microsleeps during periods when they should be alert? Working on miniature systems for collection of sleep data. Need to develop high speed transmission because of massive amounts of data.	long	<.0001	data rec video		Sleep structure studies would last between 7 days and 3-4 months.
58. Dr. Emile Levy Centre de Recherche Hopital Sainte-Justine 3175 Ch. Cote Ste-Catherine Montreal, P.Q Bus (514) 345-4626 Res (514) 744-1923	Blood lipids	To examine the effects of microgravity on the composition and concentration of lipids in circulating blood. Evaluation of the composition of lipoproteins and their metabolism.					
59. Prof. Harvey Moldofsky U. of Toronto, Center for Chronobiology Dept. of Psychiatry, The Toronto Hospital, Toronto-Western Div. 399 Bathurst St. Toronto, Ont. M5T 2S8 Bus. (416) 369-5109 Res. (416) 369-4964	Sleep-Wake Physiology	Propose to evaluate the effect of space flight on sleep-wake physiology, immune functions (e.g. plasma, interleukin) and the physical and mental well-being (fatigue and sleepiness) of man.	long *	.0001	video data rec cont sys light control special handling		People in space. Has budget for time isolation system on earth. For humans and small animals.
60. Dr. D.C.F. Muir McMaster University 1200 Main Street West Hamilton, Ont Bus (416) 525-9140 x 2333 Rres. (416) 648-6839	Pulmonary Physiology	Would like to study pulmonary physiology at low gravity with particular interest in deposition of aerosols in the lung on prolonged space flights.	minutes*	<.0001*	data rec*		Aircraft not suitable. Uncertain about facilities and microgravity level.

NOTE: a * indicates infrastructure required.

Physiology cont'd

Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
61. Prof. D. Regan Co-Director, Human Performance in Space Lab, ISTS Dept. of Psychology, BSB York University 4700 Keele Street North York, Ontario M3J 1P3 Bus. (416) 736-5627	Eye Damage	Proposes to measure functional loss in eye by light scattered within the eye. Will measure 6 months before, immediately before, immediately after and 6 months after a space mission to see if eye damage occured.	hr/days* long *		data rec*		Visual tests to be performed on ground before flight, immediately after and at 3 month intervals thereafter.
62. Dr. Peter Suedfeld Dept. of Psychology U. of British Columbia 2136 West Mall Vancouver, BC V6T 1Y7 Bus. (604) 228-5713	Psychophysiology	Interest in psychological and psychophysiological aspect of space flight such as stimulus restriction, monotony, isolation, confinement, privacy, territoriality and group development.	hr/days* long		cont sys data rec* video		Can use any microgravity.
63. Dr. Robert Thirsk Canadian Space Agency NRCC Bldg. M-60, Ottawa, Ontario K1A 0R6 Bus. (613) 993-1051	Cardiovascular System	To measure venous compliance, or tone, of the veins in the leg, before, during and after the mission to see whether it changes during space flight. To evaluate and design anti-gravity suits to counter adverse cardiovascular effects.					
64. Dr. Teresa Trippenbach Dept. of Physiology McGill University 3655 Drummond Street Montreal, PQ H3G 1Y6 Bus. (514) 398-4331 Res. (514) 484-0372	Respiratory System	Distribution of alveolar ventilation and pulmonary blood flow depends on gravity so the ventilation/perfusion ratio and therefore oxygen uptake may differ in space from that at sea level. Study short and long-term effects of reduced gravity on respiration.	25 sec * minutes	.5-.01 .0001 * <.0001	cont sys* data rec* atm cont* thermal		Wants repeated records of 1 minute tests.
65. Prof. Douglas Watt Aerospace Medical Res. Unit McGill University 3655 Drummond Street Montreal, PQ H3G 1Y6 Bus (514) 398-6025 Res (514) 695-3684	Ten topics	Vestibulo-spinal; control of gaze; visual-vestibular; muscle mechanics; proprioception; locomotor control; postular control; tactile acuity; taste and smell; space motion sickness.					

Appendix II
Material Sciences Summary

NOTE: a * indicates infrastructure required.

Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
Metals/Alloys							
1. Prof. Richard Harris Dr. Martin Grant Department of Physics McGill University Ernest Rutherford Physics Bldg 3600 University Street Montreal, Quebec H3A 2T8 Bus. (514) 398-6522	Non-equilibrium processes and non-conventional materials.	Study of the process by which an unstable super-cooled liquid solidifies by the release of latent heat at the liquid-solid interface; study of the non-linear shapes of solidification fronts in zone-refined alloys; experimental work is supported by a theoretical group. Investigations are undertaken within the recently formed Centre for the Physics of Materials.					Investigators are theoreticians and simulators; experimentalists in the Centre may well be interested in experiments in microgravity.
2. Dr. H. Henein 606 Chemical-Mineral Bldg. University of Alberta Edmonton, Alberta T6G 2G6 Bus. (403) 492-7304 Res. (403) 988-9686	Relationship between cooling rate and the solidified microstructure of metals and alloys.	Study of high cooling rate regimes with high degrees of undercooling using atomization techniques; droplets of controlled size are candidates for study in Space. Particle diameters are about 100 microns, and cooling rates of up to 1000K/s are expected to be achieved, exceeding by 2 orders of magnitude the unidirectional cooling rates for ingots.	minutes*		furnace * cont.sys* data rec* video thermal * laser	> 1 cuft	Wants to discuss his ideas with someone who has experience working in microgravity.
3. Dr. W. J. D. Shaw Dept of Mechanical Engineering University of Calgary Calgary, Alberta T2N 1N4 Bus. (403) 220-5801 Res. (403) 288-7562	Solutions of hydrocarbons, carbon, oxygen and oxides in an aluminum matrix.	Microgravity studies could lead to a better understanding of processes occurring due to mechanical alloying of materials; possible development of new materials. Work on electrochemical corrosion in microgravity to study surface phenomena.	hr/days*	.0001 *	furnace * data rec* thermal *	1 cuft *	
4. Prof. J. K. S. Wan Department of Chemistry Queen's University Kingston, Ontario K7L 3N6 Bus. (613) 545-2627 Res. (613) 389-1965	Microwave catalytic processes in a microgravity environment.	Study of the distribution of "metal particles" in fluids using a microwave catalytic technique for material and chemical reactions and processing; microgravity may provide the environment for the "ideal" experiments in which the small metal particles can be freely suspended/distributed in a fluid.	min * hr/days	.0001 * <.0001	microwave (provided by user)* video	1-2 cuft	User would provide microwave system, sealed samples; all chemical analyses could be done on earth. Experiment per sample would last only a few minutes.
Ceramics/Glass							
5. Prof. Z. Altounian McGill University 3600 University Street Montreal, Quebec H3A 2T8 Bus. (514) 398-6535 Res.	Studies of rapidly solidified materials.	Study of the formation and crystallization of metallic glasses in microgravity; possible to avoid heterogeneous nucleation and thus lead to the formation of metallic glasses with high resistance to crystallization; will use containerless technique.	~20 sec* minutes	.0001 *	furnace * cont sys* data rec* thermal *	> 1 cuft	Exact microgravity required cannot be defined at present.

NOTE: a * indicates infrastructure required.

Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
Ceramics/Glass cont'd							
6. Dr. Alain Pierre Dept of Metallurgical Eng. University of Alberta Edmonton, Alberta T2G 2G6 Bus. (403) 492-2232 Res. (403) 435-9594	Synthesis of homogeneous multicomponent colloidal ceramic gels.	Use of the sol-gel process to synthesize superconductor materials not obtainable by conventional ceramic processing; use of microgravity may overcome problems encountered when some cations precipitate or gel separately; could lead to materials with superior critical current.	hr/days	.5-.01	furnace thermal	> 1 cuft	
Semiconductor Studies							
7. Prof. Cetin Aktik Department of Applied Sciences University of Sherbrooke 2500 boulevard Sherbrooke Sherbrooke, Quebec J1K 2R1 Bus. (819) 821-7784 Res. (819) 565-4898	Radiation damage in semiconductor devices induced by high and medium energy particles.	The investigator expects to make many types of devices with different semiconducting materials with the object of studying the process of degredation resulting from radiation; the most resistant device will be determined.	minutes	.0001	furnace * cont sys* data rec* video * thermal	< 1 cuft	
8. Prof. Michael Cocivera Department of Chemistry University of Guelph Guelph, Ontario N1G 2W1 Bus. (519) 420-3960 Res. (519) 821-2613	Electrodeposition of thin film semiconductor materials for fabrication of photovoltaic and detector grade devices.	Electrodeposition of thin films requires very little material to fabricate detector grade materials; large areas can be covered. Electroactive materials dominate the electrochemical process; purification of source materials is not stringent. This advantage should be more evident in the absence of convection in microgravity.	~20 sec* minutes hr/days	.5-.01* .0001 <.0001	cont sys* data rec* thermal * video	> 1 cuft*	
9. Prof. Steen Dannefacer Department of Physics University of Winnipeg 515 Portage Ave. Winnipeg, Manitoba R3B 2E9 Bus. (204) 786-9754 Res.	Comparison of terrestrially-grown semiconductor materials with materials grown in space.	Positron annihilation spectroscopy is used to investigate point defects and other structural defects in semiconductor materials - silicon and GaAs. It is proposed to compare space-produced materials with those grown terrestrially.	hr/days*	.0001	furnace * thermal *	> 1 cuft*	
10. Prof. Sadek Dost Dept of Mechanical Engineering University of Victoria Victoria, B.C. V8W 2Y2 Bus. (604) 721-8898 Res. (604) 721-1894	Mathematical modelling and computer simulation of crystal growth from the liquid phase under microgravity conditions.	Liquid phase epitaxy (LPE) growth of silicon; low temperature solution growth of triglycine sulphate crystals; LPEE growth of GaAs. Mathematical modelling and computer simulation of crystal growing in space (combined with experiment) may provide information for future space experiments on the effect of convection, the time required to grow a desired crystal, and the optimal temperature program.	hr/days* long	.0001* <.0001	furnace* cont sys* data rec* thermal * video	> 1 cuft*	

NOTE: a * indicates infrastructure required.

Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
Semiconductor Studies cont'd							
11. Prof. S. M. Faruque Dept of Electrical Engineering Concordia University 1455 de Maisonneuve Blvd. Montreal, Quebec H3G 1M8 Bus. Res. (514) 630-7746	Investigation into the vulnerability of semiconductors and VSLI circuits to radiation.	Radiations in space are a concern for satellites, planetary travel and deep space porbes. Design of radiation hardened devices requires a knowledge of space-vulnerability. Crystal defects may be reduced by growth in microgravity.	long	0.0001	furnace cont sys data rec* video thermal * other *	> 1 cuft	"Other" required facility not specified.
12. Prof. Harry E. Ruda Dept of Metallurgy and Materials Science University of Toronto 184 College Street Toronto, Ontario M5S 1A4 Bus. (416) 978-4556 Res.	Study of MBE and laser processing of electronic materials in space.	The study of crystal growth and materials processing of electronic materials in micro-gravity using MBE and laser processing.	.5-1 * 15-25 * minutes* hr/days long	.01 * .0001 * < .0001	furnace cont sys data rec	1 cuft * > 1 cuft	
Liquids/Catalysis							
13. Mr. Jen-Shih Chang Dept of Engineering Physics McMaster University Hamilton, Ontario L8S 4M1 Bus. (416) 525-9140 Res. (416) 387-3315	Study of droplets and bubbles in microgravity.	The study of the behaviour of suspensions (droplets and bubbles) in gas-liquid two-phase systems is important for the understanding of the production of existing and new materials in microgravity. When buoyant effects are reduced by several orders of magnitude, bubbles will undergo motion due to a number of mechanisms. Motion can be controlled by electric fields. Studies in microgravity can clarify effects of fields.	15-25 * minutes hr/days	.01 * .0001	furnace cont sys data rec* thermal	1 cuft * > 1 cuft	
14. M. J. P. Dodelet INRS-Energie 1650 Montee Ste-Julie C.P. 1020 Varennes, Quebec J3X 1S2 Bus. (514) 468-7742 Res. (514) 649-6247	Application of a non-noble metal to the reduction of oxygen in a fuel cell.	The study deals with the investigation of non-noble metal catalysts for the reduction of oxygen in fuel cells. It is related to space through the use of fuel cells in space vehicles. The study would deal with the correlation of catalytic properties with structure.					Role of microgravity not specified.
15. Prof. Ulrich J. Krull Department of Chemistry Erindale Campus University of Toronto 3359 Mississauga Road North Mississauga, Ontario L5L 1C6 Bus. (416) 828-5437 Res. (416) 820-3574	Preparation of monolayers of surfactants at interfaces where molecules are closely packed and order controlled with precision.	Control of the distribution of mixed phases at a microscopic level and of the density and spatial orientation of functional groups at the surface of a monolayer at a molecular level; space may provide opportunity to develop and investigate monolayers of greater regularity and "perfection" than can be achieved in the laboratory. Studies directed toward monolayers at air-water interfaces and self-assembly of molecules onto a surface by covalent attachment.	minutes* hr/days	.0001 *	cont sys* video thermal *	1 cuft *	Video highly desirable; >1 cuft if video available Reaction times long for molecular assembly on surface to grow film w/o defects.

NOTE: a * indicates infrastructure required.

Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
Liquids/Catalysis cont'd							
16. Dr. Francois Quiron INRS-Energie 1650 Montee Ste-Julie C.P. 1020 Varennes, Quebec J3X 1S2 Bus. (514) 468-7781 Res. (514) 374-2085	Microgravity verification of ground level simulation of the surface properties of dispersions in a microgravity environment.	Verification in microgravity of results obtained on Earth on the preparation of materials involving the dispersion of a liquid or solid phase into a suspending liquid. Most results would be obtained through ground level simulation of microgravity and only a few experiments would be performed in space.					Concerned mostly with Earth-bound experiments.
17. Mr. Douglas Ruth Dept of Mechanical Enginering University of Manitoba Winnipeg, Manitoba R3T 2N2 Bus. (204) 474-9803	Study of flow in porous media in microgravity.	Study of capillary flow problems in a gravity-free environment.	15-25 * minutes hr/days	.0001 * <.0001		> 1 cuft*	Would like 16 cuft - but no reasons given!
18. M. Jean-Marie Gagne Ecole Polytechnique C.P. 6079 Succ. A Montreal, Quebec H3C 3A7 Bus. (514) 340-4732 Res. (514) 655-5752	Optical laser and millimeter wave techniques for in situ study of liquids and crystallization in microgravity.	The first objective is to bring to bear the expertise of the group to develop instruments to measure the properties of liquids and crystallization in solution in microgravity. The second objective is to grow crystals from liquids with properties difficult or impossible to obtain on Earth. Materials of interest relate to non-linear optics and biology.					Primarily interested in instrument development.
Heat Flow/Transfer							
19. Prof. Le H. Dao INRS-Energie 1650 Montee Ste-Julie C.P. 1020 Varennes, Quebec J3X 1S2 Bus. (514) 468-7744 Res. (514) 449-2432	Study of porous solids showing capillary exchange phenomena.	Study of materials having a bi-porous structure and occurring in a solid or flexible form. The experiment has two parts, preparation of materials and measurement of heat flow. Experiments in microgravity would follow those on Earth.					Experiments in microgravity to come later.
20. Mr. Masahiro Kawaji Dept of Chemical Engineering and Applied Chemistry University of Toronto Toronto, Ontario M5S 1A4 Bus. (416) 978-3064 Res. (416) 233-9420	Investigation of two-phase flow and boiling/condensation heat transfer in microgravity.	Study of phase separation between gas and liquid in the absence of gravity, where other forces control the processes. This leads to the study of two-phase flow behaviour and heat transfer in anticipation of the development of hardware for use in microgravity making use of these phenomena. Note: Currently involved in the space program.	hr/days*	.01 * .0001	data rec* thermal * video * other	> 1 cuft*	May require external venting.

NOTE: a * indicates infrastructure required.

Investigator	Subject	Description	Duration	g-level	Facilities	Size	Notes
Heat Flow/Transfer cont'd							
21. Mr. Valko Valkov INRS-Energie 1650 Montee Ste-Julie C.P. 1020 Varennes, Quebec J3X 1S2 Bus. (514) 468-7739 Res. (514) 670-9332	Effect of microgravity on transport phenomena in change of phase and biphase flow; Capillary flow in porous solids; thermochemical heat storage to control space equipment.	1. Effect of microgravity on evaporation and condensation of ammonia. 2. Capillary transport phenomena in porous solid materials. 3. Study of a thermochemical storage apparatus in microgravity conditions. 4. Materials, porous solids with capilliary exchange phenomena.	minutes minutes hr/days minutes	.0001 .0001 * <.0001 .0001 *	data rec* video data rec* data rec* thermal * data rec*	< 1 cuft* < 1 cuft* > 1 cuft < 1 cuft*	
Instruments/Techniques							
22. Dr. Harold Davis Department of Physics University of British Columbia 6224 Agricultural Road Vancouver B.C. V6T 2A6 Bus. (604) 228-2961 Res. (604) 224-6144	Motion isolation mounts.	Collaboration with Bjarni Tryggvason in KC-135 flight. Interest is in developing systems which could provide experiments with improved "microgravity" by isolating the experiment from the environment.	25 sec *		cont sys* data rec* video	1 cuft *	
23. Dr. John Feddes Dept Agricultural Engineering University of Alberta Edmonton, Alberta T6G 2H1 Bus. (403) 492-0105 Res. (403) 487-2648	Fibre optic lighting system for horticultural crop production.	Orientation of fresnel lens at end of fibre cable determines wave length of transmitted light. Optimum wave lengths to promote growth can be selected. Temperature and amount of light can be controlled.	long		cont sys* thermal * data rec other	> 1 cuft*	Fresnel lens must be directed toward sun by a control system.
24. Prof. Esam M.A. Hussein Dept of Mechanical Engineering University of New Brunswick P.O.Box 6400 Fredericton, N.B. E3B 5A3 Bus. (506) 453-4513 Res. (506) 459-7849	Development of devices to measure two-phase (boiling and condensation) flow in micro-gravity.	There is a perceived need for devices that measure the volume distribution of phases (boiling and condensation) as well as the interfacial area. Better measurements will lead to the development of improved two-phase flow space systems.	15-25 * long	.01 * .0001 <.0001	furnace cont sys* data rec* video * thermal	1 cuft *	
25. Prof. W.G. Richarz Dept of Mechanical and Aeronautical Engineering Carleton University Ottawa, Ontario K1S 5B6 Bus. (613) 788-5685 Res. (613) 249-3361	Study of noise control in a manned space environment.	Acoustical energy is not dissipated in space vehicles due to light-weight construction. Sound incident on structures can induce levels of acceleration up to 0.001 g. The effects of accelerations of this magnitude require study.	15-25 *	.01 *	cont sys	1 cuft	

Investigator Structure/Damage	Subject	Description	NOTE: a * indicates infrastructure required. Duration	g-level	Facilities	Size	Notes
26. Prof. Andreas Mandelis Dept of Mechanical Engineering University of Toronto 5 King's College Road Toronto, Ontario M5S 1A4 Bus. (416) 978-5106 Res. (416) 694-2735	Photothermal monitoring of destructive reactions at surfaces exposed to space environments.	The rate of deterioration of coatings used on space vehicles will be measured using a variety of sensors. Work will start in the laboratory, simulating the deterioration experienced in space. Detection is effected on the metal (inside) of the shell and will employ piezoelectric, pyro-electric, laser probe, and interferometric sensors.	long *		data rec* thermal	1 cuft *	Experiment to be repeated at regular intervals; each experiment lasts 1 hour. PI states that he can work under any microgravity conditions!
27. Prof. Andrew Ng Department of Physics University of British Columbia 6224 Agricultural Road Vancouver, B.C. V6T 2A6 Bus. (604) 228-3191 Res.	Effect of hypervelocity impact on structural and coating materials for the international space station.	The laboratory has developed a hypervelocity impact facility for study of materials under extreme conditions. The facility comprises a two-stage light-gas gun incorporating a 3-m long,50-mm bore pump tube and a 3-m long, 20-mm bore launch tube. This facility can be used to explore materials research pertinent to space station applications.					Work will be done on Earth.
28. Prof. Robert H. Prince Department of Physics York University 4700 Keele Street North York, Ontario M3J 1P3 Bus. (416) 736-5249 Res.	Investigation of spacecraft-environment interactions in low earth orbit.	Development of instrumentation and techniques to determine incident atomic oxygen and local energy fluxes. Note: investigator active in space now.					
29. Dr. Cho W.S. To Dept of Mechanical Engineering University of Western Ontario London, Ontario N6B 5B9 Bus. (519) 679-2111-8311 Res. (519) 657-1809	Bifurcation analysis and reliability studies of space station models.	Study of higher codimension bifurcations and non-linear stability of finite dimensional nonlinear space structures and the global properties of bifurcations in parameter space. Reliability investigation will concentrate on one specific space station model excited by various forces.					Theoretical.

Appendix III
Summary of Contracts in Place

3.1 Electronic & Electro-Optical Materials

Investigator	Subject	Description
1. Dr. E. Normen Canadian Astronautics Ltd.	Floating-zone semiconductor facility for microgravity.	During this final phase of the contract to develop a float-zone furnace for refining of semiconductor materials, CAL will integrate and test the final ground-based configuration of this sophisticated furnace consisting of a toroidal elliptic mirror using a ceramic heating filament as a heat source, a traversing mechanism for the heater, and an acoustic ultra-sonic detector for determining the float zone length as well as the shape of the solidification front. Feedback from the ultra-sonic detector to the operation of the furnace will be completed during this phase to result in a fully-automated, state-of-the-art furnace. Johnson-Matthey has provided CAL with high purity Germanium rods for further float-zoning, and characterization of these rods has indicated that although zone refining did achieve promising results, handling procedures for the crystals caused serious problems. Three best effort samples were sent to Aptec for fabrication into gamma-ray detectors. CAL is considering taking out a licence from NRC to pursue ground-based (or space-based) markets for this equipment.
2. Dr. Ted Bryskiewicz MPB Technologies	Experiments on the crystaal growth of GaAs(In) by LPEE in microgravity.	During phase II, MPB developed a prototype version of CHAMPS. CHAMPS is a modular Get-Away-Special for the Space Shuttle, and provides power, data acquisition, and thermal control, so the experimenter has to supply only the furnace core (or other experiment). Prof. D. Walsh, McGill will be providing the LPEE (Liquid-Phase Electro-Epitaxy) equipment for the payload. Phase III covered the testing of the prototype CHAMPS, and the development of a flight version, as well as its flight as a GET Away Special on the Shuttle. The experimentt unit is being developed by McGill University, with MPB assistance, and consists of cells for growing Gallium Arsenide by LPEE. Phase IV will perform the final testing of the hardware which will be shipped to Kennedy Space Center.
3. Dave Beattie SED Systems Project Manager Brent Bollong Johnson-Matthey Ltd. Principal Investigator	A program for the production of large area CMT.	Following the initial successful experiment to produce Cadmium Mercury Telluride (CMT) on the Swedish MASER rocket in 1987, the next stage is to produce large-diameter CMT crystals. CMT is produced in an ampoule under high internal pressure. In order to produce large diameter samples, yet still maintain ampoule integrity, the pressure external to the ampoule will have to be increased as the pressure inside the ampoule changes. Phase IB is the development of critical technologies for a method of sensing the pressure inside the ampoule.
4. Dr. A. Fuh Dr. O. Caporaletti ORTECH International	Study of liquid crystal-polymer mixtures in a microgravity environment.	In Phase I, ORTECH studied the feasibility of utilizing a low-gravity environment to process a new electro-optical material with improved characteristics for use in liquid crystal displays. The key material is a nematic liquid crystal dispersed as microdroplets in a polymer matrix. A reduced gravity environment and a good control of the polymer's curing rate appear to offer optimum process conditions for the liquid crystal-polymer mixtures. In Phase II, ground-based studies were focused on finding a mixing process that can speed up the polymer's curing rate without affecting the opto-electronic characteristics. These studies will be continued in a follow-on phase in FY 90/91.
5. Dr. Kim Fjeldsted Crystar Research Inc.	Experimental microgravity flux crystal growth.	Beta Barium Borate (BBO) is a non-linear electro-optical material. When a laser impinges on BBO, the frequency of the output beam contains harmonics of the input beam. This frequency-doubling or tripling capability can be used to generate lasers in the ultraviolet region of the spectrum, by impinging a red laser onto a BBO crystal. In Phase I, completed in December 1989, Crystar modified one of their furnaces and grew a crystal of BBO, using flux crystal growth. (A flux is a solvent.) Phase II will delineate the effects of gravity-driven convection on the quality of BBO, and will also cover the conceptual design of microgravity hardware. Mathematical modelling of the heat transfer and fluid flow of BBO crystal growth will also be done.

3.2 Crystal Growth and Solidification

Investigator	Subject	Description
1. Jim Ramsden Thermazone Engineering Prof. Reg Smith Queen's University	A study for the development of a compact gradient freeze furnace for controlled growth of high quality crystals.	Thermazone is designing and building an eight-zone, large-diameter version of the QUESTS furnace, for use in controlled growth of crystals. In a six-month study contract ending in 1987, Thermazone designed and constructed a protoytpe, which allows the temperature gradient to be precisely controlled and varied by computer. The furnace will handle samples with diameter 25 mm, and length up to 250 mm, at temperatures of up to 1250 degrees C. Under the Phase II contract, Thermazone is completing the design of the ground-based furnace and control system.
2. Prof. R.W. Smith Queen's University	Influence of microgravity on the microstructure and properties of eutectics and peritectics.	The Manganese-Bismuth alloy system has a ferromagnetic phase that has useful magnetic properties. Solidification under microgravity by other researchers has achieved small rods with enhanced magnetic properties. Significant benefit in understanding and control could be obtained by further microgravity studies, in particular, freezing eutectic and near-eutectic samples at small growth rates. The preceding phases were concerned with ground-based studies of eutectic and near-eutectic alloys. The Phase III investigations aim at the achievement of the following objectives: determination of the phase equilibria in the Bi-Mn-X and Bi-Mn-X-Y alloy systems and determination of the compositions and phases (X and Y are metals such as Ni, Cu, Sb, Ti, Zn): determination of the manner in which the microstructural features arise in the above eutectic and near-eutectic alloys in the range of 0.1 to 700 cm/h; preparation of eutectic samples for microgravity studies; and design of a KC-135 experiment to study the growth of the optimum eutectic in a reduced gravity environment.
3. Prof. M.C. Chaturvedi Dr. K. Tandon Dr. J.R. Cahoon University of Manitoba	Development of equipment and technique to study solidification in microgravity.	The effect of microgravity or absence of convective mixing in liquid alloys is being investigated to determine the extent of inverse segregation present in the dendrites in the solified ingot. In Phase I, two furnaces and chill apparatus were used to produce uni-directional solidified ingots of A/-5%Cu in a ground-based study. In Phase II the effect of gravity on segregation in the Al/Cu and Pb/Sn alloys under unidirectional solidification in the direction of the g-vector and opposite to it is investigated both on the ground and on the KC-135. In preparation for a sounding rocket experiment on the influence of high g on the segregation and microstructure of the alloy ingots and on the crucible assembly is investigated using a centrifuge built for this purpose. Feasibility of melting and segregation of the ingot during the rocket flight microgravity period is also investigated.
4. Dr. Jin-Jun Xu McGill University	Interfacial wave theory for dendritic structure of crystal growth.	The aim of this study is to establish the interfacial wave theory to demonstrate the essence and origin of the side-branching structure of dendrite growth from a pure melt. Specific objectives of the Phase I work are: establishment of the mathematical model for solidification from the pure melt and confirmation of the wave mechanism identified by the interfacial wave theory in terms of numerical solutions; determination and computation of the global model solutions and eigenvalues for the perturbed state of dendrite growth; and verification of numerical results by comparison with available experimental data. It is expected that the same approach can be applied to more general solidification systems such as solidicifation from binary alloy systems and solidification with fluid motion.

3.3 Glasses and Ceramics

Investigator	Subject	Description
1. Dr. E. Prasad B.M. Hi-Tech	Microgravity processing of materials for infra-red optics and sensors.	The objective of this program is to develop a range of fluorozirconate glasses that can be used for various electro-optical devices, including low-loss fibre optics. Phase II ran from October 1986 to March 1988, and systematically investigated the glass-forming region of the fluorozirconate system, as well as characterized the glasses. Preliminary design work was done on a new type of aerodynamic levitator, so that containerless processing may be done in one-g, to identify further the appropriate materials for study in microgravity. In addition, a glass processing furnace was developed for use on the KC-135, and was flown in March 1988 in a company-funded experiment. Phase III covered additional ground-based experiemntal work to improve the quality of the glass materials through control of crystallization and purity of the starting materials. Further design work was done on the aerodynamic levitator. A glass processing experiment was flown on the KC-135 aircraft in October 1988, and an automated furnace system was developed for an experiment which was flown on the T-33 aircraft in March 1989. Phase IV covers microgravity investigation of the kinetics of phase separation and crystallization of flourozirconate glasses. This includes completion of an automated glass processing furnace, for low gravity experiments to be performed on the T-33. Technology will be developed to purify the materials and thus produce glasses with lower transmission losses. The purified materials will be used to produce optical quality bulk optics 1 cm thick and 20-30 mm diameter. In addition a preliminary design report on a glass fibre drawing system and process hardware for a rocket experiment will be completed.
2. Carman Rucker AASTRA Aerospace	Performance of exploratory experiments for ceramic processing in space.	In Phase II, AASTRA was investigating sol-gel processing of two materials: - Silicon Carbide Reinforced Alumina, and - Zirconia Toughened Alumina. Ground based experiments were performed, and an apparatus was developed for flight on the NRC T-33 microgravity aircraft. A preliminary flight was done to check out the interface with the T-33 computer system, and additional flights were done in Februsry 1989 to do sol-gel processing. In Phase IIB, AASTRA is continuing to investigate the sol-gel processing of two meterails, Alumina/Silicon Carbide and Alumina/Zirconia Composites. In addition, AASTRA is exploring the advantages of microgravity processing in bioceramics. In particular, this will focus on a new porous zirconia aerogel for bone implants. In total six T-33 flights are scheduled in this phase.
3. Dr. B.H. Fox ORTECH International Subcontractor: COM DEV Ltd.	Fabrication of novel high performance magnetic ceramics by rapid solidification under microgravity.	ORTECH International is investigating the production of a high quality glass-ceramic with a magnetically-active primary crystalline phase. The ceramics would be used in millimeter-wave communication devices, and other advanced applications. In a six-month Phase I contract ending July 1987, a preliminary experimental study identified starting material compositions feasible for microgravity fabrication trials. Conceptual hardware designs for rapid solidification techniques were completed for parabolic aircraft experiments, and initial contacts with interested Canadian industries were made. Phase II entails a comprehensive study of the fabrication and characterization of the new magnetic ceramic materials. The preparation, implementation and analysis of a set of experiments on a KC-135 flight will be done, and further assessment of commercialization opportunities will be carried out.
4. Ms. Lydia Luckevich ORTECH International	High performance ceramic powder spheres and ball bearings by the sol-gel chemical process.	ORTECH is using a new Sol-gel technique for producing ceramic microspheres in microgravity, which will, hopefully, enable them to achieve uniform size and larger size relative to the one-g process. The final ball-bearings would have strategic applications in industrial use (i.e., high-temperature gas turbine engines, diesel engines, etc). In Phase 1, which ended July 1987, hardware was developed and an experiment was flown on the KC-135 in February 1987, producing ytterium aluminum oxide spheres up to 2 mm in diameter (1000 times larger than those produced at 1g). A surprising result was that the larger spheres were hollow in the center, as the sol in the center did not fully react. An additional KC-135 flight was done in October 1987, at ORTECH expense. The major emphasis of Phase II was the preparation for March/89 and February/90 KC-135 experiments of an optimal structural ceramic composition and the development of methods for producing both solid spheres (for use as ball bearings) and hollow spheres (for transducer applications).

3.3 Glasses and Ceramics cont'd

Investigator	Subject	Description
5. Prof. G.P. Johari McMaster University	Nucleation, crystal growth and liquid/liquid phase separation studies in inorganic glasses, glassy-metals and polymers.	The objective of this program is to study the crystallization and liquid/liquid phase separation in molten glass. In Phase 1, material systems were selected for study on earth and in microgravity, and a conceptual design was developed for microgravity experiments. In Phase II, a crystallization apparatus (CRYSTI) has been developed for a March/89 KC-135 flight. Ground as well as airborne zero-g experiments were done on the nucleation and crystallization of Fe-Ni-B glassy-metal alloys, Barium-Borate glasses, and amorphous polymers. In Phase III, work continued on the following tasks: improvement on the design and the capabilities of crystallization apparatus; crystallization and phase separation experiments in microgravity environment aboard the KC-135 aircraft (February/90 flight); analysis of the microstructure of the materials by X-ray diffraction, and optical and electron microscopy; and literature review on Rayleigh-Benard convection formalism and on thermal diffusion relevant to microgravity studies.
6. Dr. F. Taheri Advanced Materials Engineering Centre	Finite element analytical techniques for ceramic production in microgravity - a hypoelastic model.	The principal goal of this project is to develop the finite element methodology for the analysis of residual stress patterns formed in both terrestrial and space slip cast ceramics. To achieve this goal, the follwing tasks are being undertaken: the collection of material property data for finite element analysis, the modelling of actual sintered ceramics bodies, the finite element analysis based on a hypoelastic model, and the evaluation of results.
3.4 Laser Materials Processing		
1. Prof. Walter Duley University of Waterloo	Development of a laser materials processing system for microgravity applications.	Phase II(a) of this contract was streamlined in order to allow for further KC-135 flights using the original York University equipment that had been integrated and updated by MPB. The contract has three key players: - MPB (Design, Development and Integration of LAMPS) - York University (Experimental Laser Work in Microgravity) - National Optics Institute (Laser Imaging Evaluations). The equipment flew on the Feb 1990 KC-135 flight, and the results using the 25W laser were successful. The dynamics of laser-induced keyhold bubble structure in water were investigated. In addition laser melting/quenching of metallic alloys was examined. Negotiations have begun with NASA in order to fly a 100W laser on the KC-135 in November 1990. The basis for the equipment is the CHAMPS module, developed by MPB for McGill University, for studying Liquid Phase Electro-Epitaxy of Gallium Arsenide in microgravity. National Optics Institute will use laser holography to measure the physical deformation and modulation of the refractive index of materials during their fluid states as well as being able to provide information on the fluid state itself. An interesting aspect will be the non-contact mapping of Marangoni flows at gas-liquid interfaces.
3.5 Foams		
1. Prof. F. Weinberg University of British Columbia	Study of the generation, movement and interaction of gas bubbles in liquid metals - Phase II.	In Phase I, an apparatus was designed and fabricated to study the generation, movement and interaction of gas bubbles in liquid metals, and tests were done for argon gas flowing through a PbSn eutectuc melt. In Phase II, mathematical models were developed to simulate the free and forced convective flow and heat transfer in melts. The behaviour of gas bubbles, liquid droplets and solid particles in various liquids was physically examined. An apparatus has been designed and built for a KC-135 flight in March/89. The KC-135 hardware includes a flow-visualization experiment, to examine the formation and movement of bubbles in zero-g. A T-33 aircraft flight was also planned in order to test a method for moving bubbles through a liquid in zero-g. In Phase III the following tasks were undertaken; analysis of data from the March/89 KC-135 flight; ground experiments related to the separation, sticking and interaction of bubbles; redesign and rebuilding of the KC-135 apparatus for the February/90 flight; experiments on generation of bubbles by chemical means; mathematical simulation of gas bubble release and transport; T-33 flight experiments (March/89 and July/89) with an experimental bubble transport apparatus constructed in previous phase; analysis of T-33 flight experiments; and design and building of a new version of bubble transport apparatus for the February/90 KC-135 flight experiment.
2. Dr. Neil Cameron Frank Taylor Fiberglass Canada Inc.	Polymer foam cell growth in microgravity.	The hypothesis being tested is that the microgravity condition will permit polymeric foams to be made which have isotropic cell structure and uniform density, provided other parameters such as dynamic viscosity and temperature are appropriately controlled. The project aim is to produce such a polymeric foam with a view to: 1. further elucidating theories of both heat transfer and mechanical performance for rigid foam insulations; 2. validating theories regarding polymer foam cell formation; 3. exploring the potential which the zero-g condition may lend to the creation of new cellular materials, and identifying potential for eventual commercial opportunities in this area. A foam producing apparatus will be flown on the November/90 KC-135 flights.

3.6 Other Materials Science

Investigator	Subject	Description
1. Dr. S. Das Gupta Electrofuels Manufacturing Company Prof. B. Alcock University of Toronto SPAR, SED Systems	Particle growth in microgravity.	The objective of this project is to elucidate further the theory and mechanisms of Ostwald Ripening (particle coarsening) of dispersed phase systems, with the aim of furnishing valuable data to support the development of a high density Li-Al/FeS battery. Batteries of this type operate at a temperature around 400 degrees C and a special isothermal heat-pipe furnace has been developed. Isothermality of +/- 0.05 degrees C at 800 degrees C has been obtained over the length of the furnace. The on-going contract covering Phase III continues the ground-based experimentation as well as the development of hardware for a rocket flight scheduled for the Fall of 1991. This rocket payload will consist of a multi-sample furnace for studying Ostwald Ripening and Metal Matrix Composites.
2. Dr. Ramen Sood Ceramics Kingston Inc.	The role of gravity and gravity-driven convection in the formation of silicon carbide/silicon nitride whiskers.	Silicon-carbide whiskers are used to improve the mechanical strength of ceramics, metals and polymers. In this project, Ceramics Kingston plans to grow SiC whiskers in microgravity, in order to understand better the role gravity plays in whisker growth. The application is for the improvement of Ceramics Kingston's proprietary process, ground-based production of a prototype 1800 degree C, controlled-atmosphere furnace. Phase II was concerned with the production of a Photoflight 1800 degree C, controlled-atmosphere furnace.
3. Dr. V.E. Merchant The Alberta Laser Applications Science & Engineering Research Institute	Weld pool dynamics in a zero-gravity, zero-atmosphere environment.	This is a fundamental study of the welding process; in particular the application and extension of the technology of laser welding to operations in a vacuum and low-gravity environment. Phase I involved laboratory experiments for gathering of fundamental knowledge on the behaviour of the molten pool created by the action of a laser beam incident on a metal. The difference between the behaviour of a molten metal in a laboratory atmosphere and a vacuum atmosphere, and the effect of the direction of the gravity vector on the molten pool, was examined. Phase II work encompasses the following tasks: numerical modelling of the heat flow resulting from welding involving three dimensional versus time calculation of the heat flow using finite element techniques; modification of the experimental apparatus constructed in previous phase to provide gas shielding for welding of alloys sensitive to atmospheric contamination and to increase the vacuum capabilities; determination of comparative welding parameters for titanium and titanium alloy Ti6Al4V; investigation of depletion of elements in welds of alloys consisting of elements with various vapour pressures; and conceptual design of a vacuum chamber for the LAMPS (Laser Apparatus for Materials Processing in Space) facility being developed by MPB Technologies Ltd.
4. Prof. R.J. Slobodrian Laval University	Etude de l'implantation ionique pour des couches protectrice des materiaux pour l'usage dans l'espace.	In Phase I, a study was done for a method of magnetically shielding the Space Station from charged particles from the Sun and galactic origins. A second part of the contract involved a systematic study of ion implantation, and its effects on hardening of surface layers of materials, in order to protect Space Station structural components from the effect of bombardment from galactic particles. Phase II consisted of two parts: (1) a study of an orbital accelerator to treat the surfaces of the Space Station, and make it more resistant to bombardment by micrometeorites, and (2) the continuation of experiments for bombardment and ionic implantation for hardeneing the surface layers of materials.
5. Prof. R.J. Slobodrian Laval University	Etude d'accelerometres de precision et des aggregats fractals en microgravite.	This project addresses two subjects: the study of fractal aggregates which can be fully investigated only in the microgravity environment, and the study of precision accelerometers for the measurement of g levels during the performance of experiments in a low gravity environment. The Phase I objectives of the fractal aggregates study are: theoretical investigations related to mathematical modelling of fractal aggregates, the interpretation of their physical constants, the development of techniques for initial exploratory ground-based and flight experiments, and the development of software for the analysis of experimental data. The Phase I objectives of the precision accelerometers study are: the critical assessment of existing instruments and their construction principles, the preparation of a comprehensive analytical description for these, the critical analysis of the existing methods for calibration of these instruments, and the investigation of algorithms for the real-time extraction of relevant information on acceleration. The results of this study would form the basis for a future design and construction of an accelerometer best suited for the flight experiments on fractal aggregates.

3.7 Biotechnology

Investigator	Subject	Description
1. Mr. Wah Kung AASTRA Aerospace	Protein crystallization in microgravity.	This short phase of the contract was to enable AASTRA to concentrate upon an area of technology which needed development in order to assist protein crystal growers on the ground and in space, using existing space hardware from collaborative partners (e.g. Charles Bugg from the USA). The Company focussed on "remote nucleation detection" as being the strategic technology to pursue. This nucleation detection equipment will, hopefully, piggy-back on existing space hardware from NASA and the USSR and, at the same time, be available for update when AASTRA get the go-ahead to build the sophisticated protein crystal growing equipment designed in a previous contract phase.
2. Dr. Jacques Lapointe Dr. Paul Roy Laval University	Cristallisation en microgravite de proteins qui intergissent avec des acides nucleiques.	In the Phase I the initial investigation was conducted concerning the two main objectives of the project: (1) To obtain crystals of GluRS (a monomeric enzyme whose primary structure is known) alone and in complex with tRNA(G)(lU) from Escherichia Coli, in sufficient quantity to study the structure with X-ray diffraction. (2) To clone from the coding gene for Beta-Lactamase OXA-1 in a vector permitting the overproduction of this enzyme. Construction of coding mutants for the cysteine in place of the normal amino acid, for several positions in this gene. In Phase II the work continued on the crystallization of the glutamyl-tRNA synthetase (GluRS) from Escherichia Coli, on the crystallization of the PaeR7 endonuclease and methylase, and on the crystallization of the OXA-1 and TEM-1 Beta-lactamases. A collaboration with AASTRA Aerospace for the development of protein crystallization hardware was also initiated in this phase.

3.8 Fluid Physics

1. Prof. I.I. Inculet Prof. J.M. Floryan University of Western Ontario	A study of the dynamics of droplet break-up.	The dynamics of the droplet break-up process under the influence of an electric field is being studied. Applications include electrostatic painting, and electrostatic agricultural spraying both from the air and on the ground. In Phase I, hardware was developed for the KC-135 aircraft. The apparatus generates water drops, pulls them apart with an electrostatic field, and photographs the process with a very high-speed movie camera. Zero-g allows the droplet break-up mechanism to be studied without dominant g-effects present. In Phase II, the hardware was flown on the October/88 and March/89 KC-135 flights. The flight experiments revealed that the droplet extends along the direction of the electric field, forms Taylor cones at the elongated ends and starts to eject several very small droplets from the cone tips, before the entire mass breaks up in two or three droplets. The mathematical analysis and computer simulation successfully reproduce the various stages of the deformation process up to the formation of the Taylor cone. Beyond the Taylor cone formation, the phenomena are not completely understood, and will require further fundamental analysis and development of new algorithms capable of handling the interface deformations at that stage.
2. Prof. D.E. Brooks University of British Columbia	Structure of a flocculated polystyrene latex under constant shear in a microgravity environment.	This is a study of the flow properties of dispersions of latex spheres in aqueous media. When the dispersion undergoes simple shear flow in a concentric cylinder device, under certain circumstances a remarkable ordering effect can occur. Visible aggregates form and arrange themselves in a regular, two-dimensional, roughly rectangular lattice, which gradually degrades as the aggregates sediment. The goal is to study and characterize this new phenomena, with space experiments if necessary. In Phase I a simple shearing device was constructed, which was used to demonstrate that the ordering effect was not an artifact caused by the imperfection of the apparatus, and to confirm that the ordering is sensitive to the magnitude of the inter-particle forces. In Phase II the work continued on the design, construction and testing of a versatile second-generation shearing device including a thermostated enclosure, microscope, video camera and frame grabber. This phase should complete the initial qualitative assessment of conditions which lead to shear-induced structuring in polystyrene latex suspensions.

3.8 Fluid Physics cont'd

Investigator	Subject	Description
3. Prof. C. Ward University of Toronto	Stability of multiphased rotating fluid systems subjected to variable gravitational forces.	The Phase I concerned the study of the factors controlling the phase stability and mass transfer between phases of rotating fluids that are subjected to different gravitational fields. The two-phase system examined is a bubble immersed in a rotating liquid-gas solution. A method was developed for predicting the equilibrium size of the bubble. In Phase II, the apparatus was built and tested on ground. The experimental results confirmed the predicted theoretical behavior of bubble. In June 1990, the apparatus will be flown on the KC-135.
4. Prof. M. Salcudean University of British Columbia	Mathematical simulation of gas bubble transport in moving liquids in low gravity environments.	In this phase, a mathematical model to simulate gas bubble trajectories in moving liquid in low gravity environments will be developed. The work will be relevant to gas bubble removal in low gravity glass making.
5. Dr. Pierre Langlois Dr. Eric Harvey L'Institut National d'Optique	Etude preliminaire pour l'elaboration d'un systeme d'analyse optique des fluides en microgravite.	This contract has been rolled into the LAMPS contract with MPB Technologies to provide laser holographic imagery for laser materials processing in space.
6. Prof. K.S. Rezkallah University of Saskatchewan	Investigation of the surface tension influence on the hydrodynamics and heat transfer behaviour in two-phase flow using a weightless environment.	The general objective of this project is a systematic study in microgravity heat-transfer and hydrodynamics in two-phase flow. The specific objective of Phase 1 is to assess the previous experimental facilities and to design a hardware test apparatus that could accurately measure the convective-heat-liquid-gas flow under microgravity conditions. The envisaged three major subsystems of the apparatus are: a thermal control system, a fluid management system and a data acquisition system. In this phase it is also intended to accomplish the design of all components and the selection of materials and instrumentation.
3.9 Combustion		
7. Prof. A.J. Seber Concordia University	Preliminary definition of experiments and procedures for terrestrial and space examination of flame structure.	The objective of this project is to examine the structure of flames in space and compare the results with that predicted and observed on Earth. The Phase I concerns the preliminary definition of the experiments and procedures required to achieve the objective. The tasks to be performed are: compilation of information about observation of flame structures, collection of information on space hardware, review of space hardware, selection of a fuel/oxidiser combination that lends itself to the investigation, preparation of Burke-Schumann and Shvab-Zel'Dovich models for computer analysis, and the design of a combustor and optical systems for imaging of mixing flows.

Additional Current Contracts

Investigator	Subject	Description
1. Prof. Sadik Dost University of Victoria	Study of the mathematical modelling and computer simulation of crystal growth from liquid phase under microgravity conditions.	The objective is to develop a mathematical model to predict the process of crystal growth from liquid phase under microgravity conditions. The first phase (first six months) of the proposal will be devoted to the study of the mathematical modelling of the following growth processes: --- Liquid Phase Electro-Epitaxy (LPEE) for GaAs, ---Liquid Phase Epitaxy (LPE) for Silicon, --- Growth of Triglycine Sulphate Crystals from an Aqueous Solution.
2. Prof. Jesko A. von Windheim Prof. Michael Cocivera University of Guelph	Electrochemical growth of thin film semiconductors in a microgravity environment.	The objective is to study the nucleation of electrochemically grown CdSe as a basis for research on electrochemical deposition of semiconductors under microgravity conditions. CdSe nucleation sites form within 25 seconds, and growth initiation and deposition time are well controlled. Consequently this process is a good candidate for experimentation in the microgravity window obtained in parabolic flight.
3. Prof. M. Kawaji University of Toronto Mr. B.N. Antar University of Tennessee Space Institute	Rewetting of hot surfaces under microgravity.	The objective is to study the physical mechanisms which govern the rewetting phenomena and to use the microgravity environment to elucidate the roles of various forces acting on the interface which affect the stability of the interface and cause vapour film collapse.
4. Dr. Toomas Kilp ORTECH International	Studies on the mechanisms of microporous assymetric membrane formation under zero gravity conditions - Phase I.	This proposal outlines a Phase I study designed to examine membrane formation under terrestrial conditions in order to highlight those process parameters and experimental conditions which will allow proper design of subsequent studies to be carried out in microgravity environments. The latter are expected to improve our knowledge of membrane fromation mechanisms which could be used to modify earth based processes as well as providing spin-off benefits in other non-directly related areas.
5. Prof. Jean-Marie Gagne Ecole Polytechnique	Fusion et atomisation par laser de materiaux en condition de microgravite dans un systeme LTS, MPB Technologies Inc.	L'objectif est d'engager dans un domaine de recherche ou le but ultime de les travaux serait d'analyser et d'observer la fusion et l'atomisation par laser de materiaux en condition de microgravite.
6. Prof. J.H. Lee Prof. R. Knystautas McGill University	Microgravity combustion of dust clouds.	The purpose of the investigation is to implement exploratory and development activty on the experimental capability to measure basic dust combustion parameters in a microgravity environment. The foremost task is to optimize the dust dispersion and suspension technique. The suspension of dust by electric field has been studied by Colver and its feasibility has been demonstrated.
7. Mr. Neil Stover Nova Scotia Research Foundation Corporation	Disintegration of liquid and slurry ligaments and drops under microgravity conditions.	The objectives of the project are to generate and examine the disintegration of ligaments and droplets of non-Newtonian liquids and slurries under a microgravity environment. The disintegrations will be visually examined to quantify the rheological and surface tension effects.