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FORM 101
Application for a Grant
PART I

Date: 2006/04/24

Family name of applicant	Given name	Initial(s) of all given names	Personal identification no. (PIN)
Fisher	Brian	D	23916

Institution that will administer the grant	Language of application	Time (in hours per month) to be devoted to the proposed research / activity
Simon Fraser	[X] English [ ] French	25

Type of grant applied for	For Strategic Projects, indicate the Target Area and the Research Topic; for Strategic Networks indicate the Target Area.
Strategic Projects	Safety and Security / Risk and Vulnerability

Title of proposal
Visual Analytics for Safety and Security

Provide a maximum of 10 key words that describe this proposal. Use commas to separate them.
Visual Analytics, Interaction Science, Collaborative Visualization, Presentation, Production, and Dissimilat, Focus + Context Techniques, Large Data Set Visualization, Multidimensional Visualization, Knowledge Discovery, Spatial and temporal data mining, Perceptuomotor performance

Research subject code(s)		Area of application code(s)	
Primary	Secondary	Primary	Secondary
2710	2716	804	1200

CERTIFICATION/REQUIREMENTS

If this proposal involves any of the following, check the box(es) and submit the protocol to the university or college's certification committee.

Research involving : Humans [X] Human pluripotent stem cells [ ] Animals [ ] Biohazards [ ]

Does any phase of the research described in this proposal a) take place outside an office or laboratory, or b) involve an undertaking as described in Part 1 of Appendix B?

[X] NO [ ] If YES to either question a) or b) – Appendices A and B must be completed

TOTAL AMOUNT REQUESTED FROM NSERC

Year 1	Year 2	Year 3	Year 4	Year 5
			0	0

SIGNATURES (Refer to instructions "What do signatures mean?")

It is agreed that the general conditions governing grants as outlined in the NSERC *Program Guide for Professors* apply to any grant made pursuant to this application and are hereby accepted by the applicant and the applicant's employing institution.

Applicant

Head of department

Dean of faculty

President of institution (or representative)

Applicant's department, institution, tel. and fax nos., and e-mail
School of Interactive Arts and Technologies
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The information collected on this form and appendices will be stored in the Personal Information Bank for the appropriate program.

PROTECTED WHEN COMPLETED

Version française disponible

Canada

Date approved by RGO: 2006/04/18

Personal identification no. (PIN)	Family name of applicant
23916	Fisher

CO-APPLICANTS

I have read the statement "What do signatures on the application mean?" in the accompanying instructions and agree to it.

PIN, family name and initial(s)	Research/ activity time (hours/month)	Organization	Signature
18082, Dill, J	15	Simon Fraser	
195175, Shaw, C	15	Simon Fraser	
211736, Rensink, R	8	British Columbia	
27659, Ben Youssef, B	8	Simon Fraser	
15786, Enns, J	5	British Columbia	

CO-APPLICANTS' ORGANIZATIONS AND/OR SUPPORTING ORGANIZATIONS (if organization different from page 1)

It is agreed that the general conditions governing grants as outlined in the NSERC *Program Guide for Professors,* as well as the statements "What do signatures on the application mean?" and "Summary of proposal for public release" in the accompanying instructions, apply to any grant made pursuant to this application and are hereby accepted by the organization.

Family name and given name of signing officer, title of position, and name of organization	Signature
Brent Sauder Director, Research Services British Columbia	
David Barr Chief Technical Officer	
William Wright Sr. Partner	
Michael Greenley President	

Use additional page(s) if necessary.
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CO-APPLICANTS' ORGANIZATIONS AND / OR SUPPORTING ORGANIZATIONS (if organization different from page 1)

Family name and given name of signing officer, title of position, and name of organization	Signature
Harold Zwick Engineering Manager, R&D	

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Before completing this section, read the instructions for the definition of collaborators in the Eligibility Criteria section of the Program Guide for Professors.

COLLABORATORS

PIN, family name and initial(s)	Research/ activity time (hours/month)	Organization
Furness, T.	5	University of Washington
Ebert, D.	5	Purdue University
Billinghurst, M.	5	University of Canterbury
Pylyshyn, Z.	8	Rutgers University
Metaxis, D	5	Rutgers University
Kasik, D	5	Boeing Corporation
Darvill, D	5	Greenley and Associates

 Use additional page(s) if necessary.

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23916	Fisher

ACTIVITY SCHEDULE
(Refer to instructions to see if this section applies to your application. Use additional page(s) if necessary.)

Milestone	Description of activities	Anticipated starting date	Anticipated completion date
Collaboration 1	Work with Canadian and international partners to refine implementation and empirical methods, build alliances and divide tasks.	2007-01-07	2007-04-07
Collaboration 2	Develop videoconferencing and shared application environment (e.g. Access Grid) with Canadian and international colleagues for biweekly and ad hoc-meetings (these continue throughout the project)	2007-01-21	2009-12-20
Interaction Science 1	Stereo depth judgment study submitted bridging lab studies and spatial perceptual judgment using existing stimuli from VA datasets (Fisher)	2007-01-21	2007-04-01
Visualization 1	Perceptual test of Idelix PDT submitted using existing VA datasets-- spatial judgments, effects of shading and stereo cues (Fisher, Rensink)	2007-02-15	2007-06-01
Interaction Science 2	Multiple onset Simon Effect study submitted, with recommendations on interaction models for human-information discourse in visually active data spaces for direct and remote manipuation of data items	2007-02-21	2007-09-07
Simulation 1	Design collaborative simulation environment for testing w. Greenley expertise & technology and HITLab HiSpace AR tabletop (Fisher, Shaw,Ben Youssef))	2007-03-01	2007-12-07
Collaboration 3	Propose conference workshop with industry partners to extend and network information science community and focus on VA problems	2007-03-01	2007-06-01
Sensemaking 1	Rework CZ for application to VA tasks & situations, extend interaction modalities for skilled use, combine visual languages and indexical interaction for what-if analysis and assessment of roles and reliability of information from participants(Fisher, Dil	2007-05-01	2008-02-01

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Milestone	Description of activities	Anticipated starting date	Anticipated completion date
Interaction Science 3	Attentional control in large-field dome display submitted with recommendations for use of wide-field-of-view displays for dynamic stimuli and changes in viewer (camera) position (Fisher, Rensink)	2007-07-14	2008-03-15
Simulation 2	Design competitive simulation for testing w. Greenley expertise & technology adapted to PARVAC wargame scenario. Adapt Oculus GeoTime to analysis of temporal data (Shaw, Ben Yousef)	2008-01-21	2008-11-01
Sensemaking 3	Wayfinding study in information displays, acquisition of mental models of display space, communication through multiple laser pointers (copresent) and spatial reference (distant) (Fisher, Dill, Rensink)	2007-06-14	2008-06-01
Simulation 3	Integrate small form-factor palmtop displays and networked interaction with central command and control for training and mission rehearsal using PURVAC scenarios (Fisher, Dill, Shaw)	2008-09-01	2009-05-07
Collaboration 4	Present implementation and testing methods at applied technical session at targeted visualization/security workshop	2008-04-01	2008-06-01
Visualization 2	Build prototyping environment for visualization testing with Oculus expertise and software, allowing annotation and argumentation for integration with sensemaking track (Fisher, Dill, Shaw)	2008-02-14	2009-08-21
Sensemaking 4	Prototype self-documenting electronic executive summaries to enable information rich discourse between visual analytic specialists and policy makers (Fisher, Dill, Rensink)	2009-03-01	2009-10-14
Collaboration 5	Final workshop	2009-02-01	2009-06-01

Introduction

Visual analytics (VA) is the science of analytical reasoning facilitated by interactive, visual interfaces. It applies information and communication technology to strategic and tactical decision making using large volumes of data of varying certainty in time, place, or substance. It augments decision makers' individual and collaborative exploration, understanding, and communication of knowledge about real-world situations to generate practical solutions to complex problems. VA builds on information visualization approaches from Computer Science and Engineering [37][8], extended to better address complex decision-making processes through application of an emerging field of investigation we are terming "interaction science". The book "Illuminating the Path: The Research and Development Agenda for Visual Analytics" by the US National Visualization and Analytics Research Centre (NVAC), funded by the US Department of Homeland Security (DHS) [36] sets forth a multidisciplinary research agenda that bridges cognitive science research in analytic reasoning and visual representation with interactive data representation and transformation: " We must build a richer and more effective synergy between research in human abilities and the design of interfaces that enable humans to use those abilities to make decisions in large and complex data spaces. Visual analytics researchers should pose questions based on the situations of use of these interfaces, and a new generation of applied cognitive scientists should work to generate methods that will focus on, examine, and ultimately answer those questions". A similar effort is taking place in Europe as a part of the 7th Framework. From the Commission report: "The following priority missions were identified...: Optimizing security and protection of networked systems. Protecting against terrorism (including bio-terrorism and incidents with explosives, biological, chemical and other substances). Enhancing crisis management (including evacuation, search and rescue operations, control and remediation). Achieving interoperability and integration of systems for information and communication. Improving situation awareness (e.g. in crisis management, anti-terrorism activities, or border control)." Recent EU efforts in Preparatory Action on Security Research (PASR) include work packages that runs parallel to our efforts (e.g. " Cognitometrics- New Approach To Study Cognitive Processes" PAS 2006) and we are in contact with key research groups through our participation as collaborators in the 6th Framework Kaleidoscope Network for Technology-Enhanced Learning.

We are seeking funding from NSERC that will enable us to bootstrap VA research in Canada and bridge the efforts of Canadian technology providers and international partners, customers, and end-users. The work described in this proposal as important for this effort, as has been explicitly recognized by collaborators in the US, New Zealand, and Australia in their inclusion of our interaction science research in their DHS funded workplans. NSERC funding will allow us to speed and integrate Canadian industry and university contributions to this broad international effort by: 1) extending our interaction science methods to address VA applications and situations, using tools and environments developed by industry partners; 2) working with partner companies to build proof-of-concept prototypes and VA applications; and 3) Extending functionality of applications developed in our university labs to enhance their commercialization potential in VA applications. Successful completion of these joint projects with our Canadian and international collaborators will provide new business opportunities for Canadian companies and new technologies to prevent loss of life and damage to property in Canada and abroad. The US R&D Agenda recognizes interaction science as critical for VA development. Our focus on this key component insures that our research findings and implementations will have application in a range of knowledge work applications. This will enhance business opportunities for partner companies and increase the ability of HQP trained in this project to apply their knowledge and skills in CAD, resource management, decision support, e-learning, and a range of other knowledge industries.

Section 1: Originality, Quality of Work, Plan, and Researchers

The goal of this broad international effort in VA was well stated in the US R&D Agenda [36] :

" We must build a richer and more effective synergy between research in human abilities and the design of interfaces that enable humans to use those abilities to make decisions in large and complex data spaces. Visual analytics researchers should pose questions based on the situations of use of these interfaces, and a new generation of applied cognitive scientists should work to generate methods that will focus, examine, and ultimately answer those questions. Goals of this collaboration are development of user models and design and testing methods that go beyond usability engineering to address individual and collaborative perception, cognition, and action in ways that :

Are precise, generating design methods and prescriptions at a greater level of specificity than the current conceptual work discussed above. The goal here is to reduce design uncertainty, generating a manageable design space for exploration and user testing.

Are diagnostic, enabling interaction designers to test how the use of a proposed design will be affected by specific key abilities as well as key bottlenecks in the user's cognitive architecture

Enable a broader class of users (e.g. analysts, older users, different cultures etc.) to have access to these technologies. This may be achieved by understanding individual differences in abilities and limitations and customizing interaction based on differences in performance at different levels of the cognitive architecture.

Support the acquisition of "interaction virtuosity", to train highly skilled users who can work with the most complex data sets with a high level of performance, perhaps using novel displays and control devices.

The common ground for this collaboration will come from a shared understanding of cognitive architecture and the nature of mental processing."

Objectives:

1) To build upon our early leadership in the emerging field of interaction science by (a) developing our research and (b) through outreach to the cognitive science community.

2) Use this research base to develop those aspects of an underlying theory of interaction science applicable to visual analytics methods and applications.

3) Leverage these research results and collaborations to support our Canadian industry partners in their effort to build visual analytics applications, tools and techniques to meet the needs of this large and growing market opportunity .

4) Strengthen our role in the international R&D effort in visual analytics for safety and security, beginning with the fulfillment of our obligations to PARVAC, PURVAC and NVAC, and continuing with European collaborators as the 7th Framework effort develops.

Successful completion of projects with our Canadian and international collaborators will advance the Safety and Security theme by providing new technologies to prevent loss of life, threats to health, and damage to property and natural resources. In addition to our work with NVAC, we have been fortunate to have contributed to two successful bids for DHS-funded $4M Regional Visualization and Analytics Centers (RVACs). The **Purdue Visualization and Analytics Centre (PURVAC)** will develop VA environments for the communication of information and insight from massive, disparate, incomplete, and time-evolving data sets. They focus on emergency planning and response, intelligence analysis, and healthcare management and monitoring. Their emphasis is on visualization, data integration, and simulation, with integration in homeland security projects.

The provisionally-funded **PAcific Rim Visualization and Analytics Centre (PARVAC)** includes researchers in U. Washington's HIT Lab, the Hawaii Supercomputer Center, New Zealand and Australia.

Dr. Fisher is a co-principle investigator of this project, and Dr. Dill is a co-investigator. Its goal is "Getting bandwidth into the brain"-- optimizing the use of human visual mechanisms for scene understanding in VA ; and to "Enable bandwidth between brains"-- to use the power of technologically-mediated human competition and collaboration to solve problems that are too complex for any individual.

Both RVACs have extensive links with US agencies and emergency service providers. We are the only Canadian university research group affiliated with any RVAC, and the only university group associated with two RVACs. In addition Dr. Dill maintains a direct role on the NVAC Agenda Panel and is an NVAC Scholar. This, combined with the broad applicability of interaction science, places us in the unique position in Canada of being able to contribute to research across the RVACS and their Eurpoean counterparts, anticipate the need for and nature of core enabling technologies, and thus generate knowledge assets that will enable Canadian companies and universities to better meet safety and security needs .

Interaction Science research approach: Our key contribution to the RVACs is "Interaction Science", an applied cognitive science of perception, cognition, and action in VA environments. We will build upon and extend scientific approaches to HCI and visualization (e.g. [6][37]), to enable developers to address the quality of decisions made by analysts and the processes that gave rise to them. This requires us to meld cognitive science and HCI at a deeper level than is needed for usability analysis. We will begin by decomposing task performance with respect to the users' cognitive architecture. We will then identify psychology and cognitive neuroscience findings that play a role in key aspects of the interaction, for example our examination [21] of the impact of changes in camera location for fishtank VR air traffic control, addressed with Pylyshyn's (1989) FINST theory and multiple object tracking task[28]. These effects will be tested and extended in "toy world" tasks and situations characteristic of the application. Finally, we will work with the application itself, often through collaboration with industry partners, to map research findings onto the "real world". It is the intermediate level of investigation that is unique to this research group, with publications on attentional tokens in fishtank VR air traffic control (with Hughes HRL), active stereo display depth judgments in automotive CAD (With GM of Canada), Multimodal driving interfaces (with Nissan), and navigation of CAD environments (with Boeing).

Application to visual analytics

In discussion with colleagues in NVAC and the RVACs we have identified three target areas where a scientific understanding can address threats to the effectiveness of VA designs. These bridge use-inspired basic research [34] and prototype and application development:

1. **Spatial Cognition in VA Environments: Seeing Patterns in Data**
2. **Enactive Cognition in VA Environments: Human-Information Dialog (Sensemaking)**
3. **Distributed Cognition in VA Environments: Collaborative and Competitive Analytics**

1.0 Spatial Cognition in VA environments: Seeing patterns in data

1.1 Display dynamics and attention management. Visual analytic displays differ from current information visualization approaches in their emphasis on dynamic data-- displays must depict events than unfold over time and must support a higher level of interaction with massive datasets, focusing on key areas, generating and testing hypotheses and scenarios, evaluating uncertainty etc. in an ongoing human-information dialog. This requires highly dynamic information display, where display items frequently change colour, shape, size, position etc. Often multiple changes will occur at the same time, leading to ”change blindness” [29][30] the robust inability of observers to detect a significant change masked by another more salient onset event, such as a blanking interval or large object onset.

The frequency of multiple object onsets within a short time frame in visual analytic and other dynamic display environments (e.g. when a display is paged or updated as a whole) may overload human abilities. Our work with FINSTs tested multiple onsets in laboratory situations and for simple display environments [33]. We will extend this to examine complex patterns of multiple onsets characteristic of VA. In addition, the display may change globally, for example, from the shift in camera position that accompanies navigation through a large data space. These global transformations (zoom, pan, rotate, etc.) may occur on the plane of the screen or in the third dimension on stereo displays or through motion in depth in 2-d perspective displays. In [2][21], we examined users' ability to monitor multiple moving elements within a complex display with other moving distractors to evaluate the impact of a move from plan-view air traffic control displays to the “flight-sim” style 2-D projections of 3-D environments in “free flight” ATC. We found that tracking performance was determined by allocentric “virtual space” rather the plane of the display or the retina. This showcased a previously unknown human ability to compensate for visual changes in point of view of moving targets in allocentric space. Subsequently we [22] explored the impact of ”cuts” in point of view using the “shaker paradigm” which tests performance for a visual task on an image that is rapidly alternated with a transformed version of itself. Our findings map out low-cost zones where transformations result in only a slight degradation of performance, generating guidelines for design of visual human-information dialogs.

While proven for the desktop flat-panel situation of use of Free-Flight ATC environments, preventing change blindness and fostering ability to monitor multiple individual display elements across global display transformations is critical for visual analytic environments that may use stereo, large field-of-view displays and more complex motion pathways, multiple target onsets etc. Fisher and Rensink will build on our previous work e.g. [2,30] to examine temporal aspects of human information processing in rich display environments with an eye towards optimizing the effectiveness of users' limited perceptual and attentional capabilities for conventional, true binocular stereo fishtank, and VR displays.

1.2 Immersive VA: large field and stereo displays. Our studies of depth perception in stereo displays [16][1][10] originated from observations by Randall Smith and colleagues at GM Research that individuals appeared to differ in their judgments of depth and size of the same object in a virtual environment. Under contract to GM of Canada, we conducted a range of studies using psychophysical testing methodologies (method of limits, method of adjustment, method of constant stimuli) and a two-alternative forced choice task to differentiate between perceptual and judgment errors in virtual vs. real environments with regards to the kinds of stimuli and judgments that support automotive CAD.

Depth judgment errors of this type can have negative consequences for VA as well. Given the different stimuli and tasks in the two applications, extension of our VR judgment studies will be required to determine what if any impact perceptual errors will have on VA, and what if anything can be done to correct them. Our work suggests that perceptually training users may help to reduce errors, and that display customization based upon an individual's “personal equation of interaction ” may also help. In the proposed project we will test the impact of frames, use of real-world sensory recalibration cues [11], and individual differences in adaptation to stereo display artifacts. Fisher and Dill will build on this to discriminate between perceptual and decision-stage effects.

2.0 Enactive Cognition in VA environments: Human-Information Dialog (Sensemaking)
Enactive cognition refers to activities that structure and support individual and group cognition. Human-

information dialog is necessarily mediated by enactive cognition. This focus addresses the cognitive science of decision evolution i.e. "sensemaking" through interactive VA.

2.1 Wayfinding in VA environments. One global transformation is navigation through a large data space, a simulation of a real-world space for training and mission rehearsals, or an abstract data space that is large enough to require a navigation metaphor for view selection. In [35] we worked with researchers from the Boeing Company to examine mental models created through movement through CAD spaces in collaborative work. Fisher and Dill will extend this work with PARVAC partner Boeing to further explore differences between active and passive navigation in CAD and other VA data spaces, the ability to retrace paths, report relationships between items in space etc.

2.2 Onsets and Perceptoumotor processing. Visuomotor performance is mediated by a second visual pathway [24]. This has been shown to have implications for design of interactive systems [25][26][27]. Pylyshyn [28] predicts that onsets will affect speeded motor performance in direct target acquisition tasks (e.g. pointing) through their impact on the corresponding attentional token in action space (called an ANCHOR). Based on our previous work (esp. [27]) we believe that the Simon SR compatibility effect is mediated by FINST/ANCHOR system. Fisher, Dill, and Rensink with support of Pylyshyn will test the impact of FINST-related performance bottlenecks (e.g. multiple onsets, change blindness) on fluency of control in the cycle of perception, understanding, query, and command that comprises the VA human-information dialog.

2.3 Temporal patterns in human-information dialog. A major stumbling block for interaction science of VA is the ongoing nature of the human-information dialog. This limits the applicability of trial-by-trial experimental psychology methodologies. Addressing the sequential nature of human-information dialog will require time-series analyses bridging human-mediated discourse analysis of video data and mathematical modeling of sequences of interaction. In addition, analysis of temporal patterns (i.e. "rhythms" of interaction, [23]) demonstrates that regularities in the temporal patterns characterize different collaborative and communicative tasks. Visual/haptic temporal correspondence has been used to individuate information presented on a public display for particular users [31]. As any Tetris player knows, interaction with technology also has rhythmic structure, and disruption of that rhythm (even if it is a slow onset of a new Tetris block) can disrupt performance. This temporal structure has been linked to the speed of cognitive processing at the most basic level [3] interpreted as indicative of a state of "flow" [8] of fluent interaction in dynamic datasets, and that changes in displays can interact with reentrant processing in visual perception to cause misperception [9]. If these theories are correct, interactions of temporal patterns in human-information dialog can interact with the intrinsic time course of cognitive processes to support or impede cognitive processing. This suggests that temporal rhythms in solo and collaborative use of technology can both detect and support "flow" of effective cognitive processing and fluency of interaction.

Testing this hypothesis within the context of VA presents technical and logistic challenges. We address the former in subsection 4.3. As VA is a new and evolving area of research there are currently few expert users of VA applications, and those that exist (e.g. air traffic controllers) are difficult to access for testing. Data sets for homeland security decision-making are not currently available, although this is being addressed by NVAC. Our approach has been to iteratively develop qualitative and quantitative analysis techniques through examination of expert interaction and collaboration in skilled performers. We have conducted pilot studies examining these factors in the control of highly skilled cooperative behaviour in extremely proficient perceptuomotor skilled subjects, classically-trained musicians using embodied discourse analysis [17]. Fisher and Shaw will continue this line of investigation with other skilled performers in interactive computer graphics, in particular with NFB film maker Jean Detheux, a real-time computer animation performer whose experience has contributed to the development of one of the most advanced interactive graphics environments, Studio Artist. This will provide a testing ground for our tools as well as giving us valuable insights into perceptuomotor performance in cognitive and creative tasks. Shaw, Ben Yousseff, and Darvill will then use those tools and methods in simulated emergency management situations through our collaboration with MDA, CAE/Greenley and in intelligence analysis situations using scenarios being cleared by NVAC for use in RVAC research.

3.0 Distributed Cognition in VA environments: Collaborative and competitive analytics

In [13][20][15] we apply theories and methodologies from psycholinguistics to collaborative environments. Both competitive and collaborative activities rely on the ability of users to develop mental representations of the belief states, goals, and intentions of other participants (i.e. "metarepresentations") through direct communication and through observation of action and inference of intent. These metarepresentations are created through a process known as "grounding" [7]. In face-to-face communication, grounding takes place largely through observation of non-verbal actions of the other party, interpreted in a framework of the roles of the participants and their current level of metarepresentation. Our work with musicians [17] has extended that work to embodied discourse analysis of nonverbal communication and coordination in the complex joint activity of playing a duet. Our analysis has led to requirements for tools to perform more sophisticated video analysis techniques that will speed the development of time-series analysis environments. As environments are generated through collaboration with MDA, CAE/Greenley and PURVAC/PARVAC, Fisher, Shaw, Ben Youseff, and Darvill will use those methods to guide the testing and iterative design of collaborative and competitive (e.g. "war games") VA environments that are being developed in the US RVACs. We have extended this framework to collaborative technology environments [13][20][15] and through the work with musicians, to face-to-face coordination in a difficult non-verbal task. This analysis will be applied to collaborative and competitive discourse analysis in the design of the environments discussed in subsections 4 and 5, where grounding may take the form of a computer-mediated human-human discourse, e.g. exchange of queries and briefings between a policy maker and an analyst that coordinates high-level decision-making with the best and most recent analyses in a timely and effective manner.

While much of our innovation stems from an emphasis on scientific approaches, success will be judged by the design of VA systems. We focus on two in-house development projects that will allow us to maintain an independent research program and two collaborative projects that will focus our interaction science work on a particular situation of use and to enable our Canadian industry partners to benefit from PARVAC, PURVAC and NVAC research and implementation.

4.0 In-house development 1: extending the CZWeb/CZTalk environment

4.1 System design: extending CZWeb. Our CZWeb and CZTalk environments (Lam et al 2005, Fisher and Dill 2000, Fisher et al 1997) explore inset zoom and layout approaches to VA on the Web and in email. This led to an SFU spin-off company (ThoughtShare Inc.) that received $8M in investment and grew to over 50 employees before the economic circumstances forced a change in business. SFU reacquired development rights for this technology, and we now propose to adapt it to VA. In CZWeb users evolved a novel pattern of organization for Web-based information through simple operations (incorporation, culling, encapsulation in cluster nodes, local detail-in-context zooming, spatial clustering and arrangement into visual (i.e. Gestalt grouping) patterns etc. These changes in the representation could be generated by the computer as the result of a change in the underlying data or by a control action (e.g. a query) by the user and **epistemic actions** [19] that are generated by the user as part of a sensemaking dialog [32]. Dill and Fisher will extend this work within the context of sensemaking in visual analytics environments, evaluating and testing visual metaphors and languages to bring together visual semantic and indexical ways of referring to and manipulating VA data.

4.2 System design: extending CZTalk. A parallel line of investigation used the CZ interaction technique to visually represent salient conversational patterns characteristic of face-to-face human discourse, essentially substituting visual cognition for the conversational pragmatics that would enable an observer to understand conversational referents, relationships, beliefs, intentions etc. of the conversants [7]. This was tested as a tool to support instructors understanding and evaluating patterns of communication in collaborative learning [38]. We will scale the application to support decision-making about conversational patterns in larger sets of participants to what-if analysis based on conversational pragmatics, e.g. determining the veracity of a participant, relationships, alliances, etc. Dill and Fisher will explore proof-of concept prototypes for merging CZWeb and CZTalk to create a unified desktop for sensemaking with data and interpersonal communications. This will draw upon much of the work described above on visual/spatial cognition, interactions rhythms, allowing us to demonstrate how findings from multiple streams of interaction science research can be combined in a single application.

5.0 In-house development 2: Temporal analysis software

Temporal analytics is the analysis of patterns of activity that unfold in time, seeking patterns of activity indicative of terrorist activity. In our second in-house project Fisher will generate a proof-of-concept level application of our embodied discourse analysis techniques to analysis of collaborative planning. Initially, our efforts will be directed to the application of temporal analytics as a research tool. Central to this effort is advanced visualization of patterns in data that support "what-if" analysis and human-information discourse. Our collaboration with MDA and Oculus is a key enabler for this line of investigation. This will serve two purposes: initially, it will enable us to analyze the human-information discourse and computer-supported collaboration data we will collect in subsection 2, and secondarily it will address the kinds of analysis that will be needed for temporal analytics, a priority for NVAC.

5.1 Collaborative application development with Canadian partners on VA applications in Canada, the US, Europe, and Pacific rim countries through the RVACs, NVAC and partner agencies and work to build European collaboration. Our role in these projects will enable us to leverage interaction science findings, proof-of-concept prototypes, and mockups built upon industry partners and in-house technology to build opportunities for participation of our Canadian industry partners. We coordinate with our international colleagues in virtual and physical meetings scheduled in the project milestones to insure a high degree of coordination.

5.2 Large-screen, virtual, augmented, and mixed reality visualization: PARVAC targets awareness, response, and recovery for situations that span a wide geographic area and demand coordinated multinational response. We will guide design and testing of these environments, with a particular emphasis on the application of MDA and Oculus's advanced visualization technologies and Idelix' PDT and PDT 3D spatially distorted detail-in-context smart lenses to VA on conventional and new display technologies. Our attention and multimodal perception work can combine with the discourse analysis work by coordinating the collaboration of multiple participants [4] e.g. by using coded-pulse laser pointers that identify the controller [37] and by implementing individual haptic cues that synchronize with particular display events as a cue for the assignment of particular display items to individual users [5]. This will be applied initially to abstract visualizations, but may also be tested with CAE/Greenley's homeland security simulation of Chemical Biological, Radiological, and Nuclear technologies, with MDA's access to satellite information and ground-level situation assessment.

5.2.1 Simulation for collaborative and competitive VA. Both RVACS RVACs place an emphasis on emergency planning and response, real-time coordination of field personnel (police, fire, emergency, medical) and decision-makers. We will attempt to integrate MDA and CAE/Greenley simulations with this research effort, making available test data that our collaborators in PARVAC/PURVAC are generating. We will use our analysis techniques to evaluate and guide the optimal use of these technologies in VA applications as they are being developed by our international partners. An example of this is PURVAC's small-screen interaction (palmtop and wearable) for healthcare monitoring and response, combining desktop strategic visualization by epidemiologists with field workers in health care and other areas that may provide information that may impact prediction of disease, e.g. veterinarians, and vendors of over-the-counter drugs, This requires the use of small form-factor devices such as palmtops and tablets that can be transported into the field, necessitating display optimization techniques such as Idelix PDT. These must allow for field workers to exercise initiative in dealing with situations on the fly-- hence their capability must not be limited to conveying instructions but must also provide information for local decision-making, such as maps and documentation for field repair of infrastructure as well as the ability to report on local conditions to update central decision-makers (e.g. medical reports for epidemiological analysis). PURVAC researchers have developed software for EPR that scales from individual business offices to an entire city. These have been tested in Measured Response training events at Purdue since 2002. We will work with PURVAC and PARVAC to design and test MDA and Greenley simulation techniques for this purpose in our lab and in MR events, building laboratory tests to focus application design that can be later tested in the field, and to apply embodied cognition testing methods developed in subsection 2.3 to the field studies themselves.

6.0 Research team and roles

John Dill is a Professor Emeritus of Engineering Science and Professor in the School of Interactive Arts and Technology at Simon Fraser University. His primary area of expertise is information visualization and visual analytics. Dill will be involved in project management, as the primary contact person with NVAC, as an expert in visualization techniques, and as an experienced collaborator with industry partners. **Brian Fisher** is an Associate Professor of Interactive Arts and Technology at Simon Fraser University and the Associate Director of the UBC Media And Graphics Interdisciplinary Centre. His area of expertise is in cognitive science-based interaction design. Fisher will be involved in project management, interaction science, testing methodologies and design guidelines. Dill and Fisher have a long history of collaboration. Together with **Rensink** and **Enns**, they were co-investigators on an NSERC Strategic grant "Collaborative Visualization for Time and Safety-Critical Situations that this proposal builds on, and an IRIS project "A Cognitive Basis for the Design of Intelligent Interfaces to Complex Systems' which started the applied cognitive science methods used here.

Chris Shaw is an Associate Professor of Interactive Arts and Technology at Simon Fraser University, and an expert in human-computer interaction, computer graphics, computer games and simulations, and immersive and ubiquitous computing. Shaw will be involved in interaction design, simulations and games. **Belgacem Ben Youssef** is a specialist in simulations, simulated video, videoconferencing, and will be involved in interaction design, simulations and games. **Ronald Rensink** is an Associate Professor in Computer Science and Psychology at the University of British Columbia. Rensink has worked with Fisher and Dill on a previous NSERC Strategic grant that helped to develop the methods and approaches in this proposal. Rensink will be involved in interaction science and testing methodologies.

David Darvill is a consultant with Greenley and Associates, previously he was Director of the Human Centred Design facility at the New Media Innovation Centre (NewMIC), Program Manager with Microsoft Corp following its acquisition of NCompass Labs, where he was Director of User Experience and Manager of Human Factors for MPR Teltech, and a scientist with the Canadian Department of National Defense, where he conducted human factors research on simulation, training and military ergonomics at the Defense and Civil Institute of Environmental Medicine in Toronto. Darvill will be involved in simulation and interaction design as well as serving as a liaison with industry and government agencies.

Other collaborators include David Ebert, PI of PURVAC, Tom Furness and Mark Billinghurst, PI and Co-Pi with Fisher of PARVAC. Zenon Pylyshyn (Rutgers) a founder and past-president of the Cognitive Science Society, Demitris Metaxis (Rutgers), who is working on security technology with the New York Port Authority, David Kasik of the Boeing Company, Jim Enns (UBC) and Nick Hedley (SFU) an investigator on PARVAC.

SECTION 2: HQP

A major focus of NVAC is fostering the training of a new generation of cross-disciplinary researchers and practitioners in the design, testing, and use of visual analytic technologies for homeland security, disaster relief, epidemiology, and other areas where augmentation of individual and collective problem solving is needed. Each RVAC is required to have a plan for training that will interact with their academic programs. We will join in the curriculum development with our partner RVACS to build training programs to support the development of Canadian VA expertise. Our programs in Cognitive Systems (UBC) and Cognitive Science and Interactive Arts and Technology (SFU) can provide us a structure within with to develop Canadian programs in this important and emerging field.
While the focus of our efforts is homeland security, our work requires us to interact with cognitive science, perceptual science, and psychology researchers to identify applicable findings and motivate investigation of cognitive operations used in VA tasks at similar levels of complexity. This will be done by building direct collaboration with researchers, through workshops and symposia at major conferences, and through developing and contributing to the development of freely available analytical tools, stimulus generation software and other enabling technologies for this work. This will provide invaluable cross-disciplinary understanding and collaboration skills for student researchers that may be applied to the development of technologies to support a broad range of knowledge-based tasks and activities. These

students will be able to find jobs in a broad range of knowledge industries and innovation groups in more traditional industries that can benefit from understanding of the use of technology in human cognition and collaboration.

As part of our internatonal collaboration we will have the opportunity to place student interns and researchers at NVAC headquarters to aid in that effort. Both RVACs have the need for student exchange written into their proposals, giving us the ability to send Canadian students to work with them and to accept US, NZ, and Australian students to work with us in Canada. The PARVAC proposal focuses on group decision-making, and will have regular meetings over Access Grid using iRoom technology augmented by technology developed at HIT Lab (e.g. their Hi-Space tabletop interface) and in the project itself. This will provide ongoing collaboration with the international community of PARVAC and PURVAC researchers, including industry and government partners at Boeing, Chance Tools, ART Toolworks, Indiana School of Medicine, Regenstrief Institute, Dept. of Health, Homeland security etc.

SECTION 3 Relationship with supporting organizations

An important aspect of this proposal is the set of relationships that we bring to the project. Unlike many proposals that seek to advance an existing relationship with a company to address a perceived opportunity in market, our project team has participated in the development of a new opportunity and has pre-existing relationships with stakeholders, creators, and shapers of that opportunity. Though the US NVAC is less than 2 years old, Dr. Dill was part of the panel that set up the structure of the US research programs, and he and Dr. Fisher participated in drawing up the plan for that program, subsequently published in the book "Illuminating the Path, the R&D Agenda". This set out a research agenda in part realized in the funding of US RVACS in 2006. We seek support to build a bridge between international stakeholders and Canadian companies who may otherwise be unable to move quickly enough to take advantage of this immediate and growing opportunity. The short timeline of this effort makes it unlikely that one could build a relationship with a Canadian company that focused specifically on this opportunity in time to affect this proposal. We therefore focused on Canadian industry partners with whom we had ongoing or prior relationships, and who have sufficient interest to work with us on proofs-of-concept that will establish for them the feasibility of their involvement in this very large market (e.g. $42B USD for the US DHS).

Co-investigator Dill spent a sabbatical at MDA in 1994, one result of which was development of a successful Precarn proposal related to analysis of large volumes of heterogeneous data[1], and retains research relationships from that period. PI Fisher has also recently been asked to consult on projects at MDA. Idelix is an SFU spin-off company started by colleagues of Dill and Fisher, and a number of ex-students are on staff. Greenley is a new collaboration, however the contact person David Darvill worked with Dill and Fisher on the Intelligent Graphics Interface project funded by Precarn. Oculus is also a new collaboration, though the contact person, a principle of Oculus, was also a member of the NVAC Research Advisory panel.

Much of the value of this project lies in the improvement of IP that is already in the hands of industry partners (e.g. MDA and Oculus visualization software and Greenley simulations) and SFU (in the case of the CZWeb/CZTalk stream). New IP will be generated (e.g. in the temporal analytics stream) and we anticipate academic use of this will remain with the university while commercial use licenses will be offered to industry partners by SFU.

[1] The company subsequently decided not to pursue the project at that time.

SECTION 4 Benefits to Canada

Research and innovation

The US is spending at last report $150 M on Visual Analytics research, coordinated through NVAC. The EU is considering a level of expenditures in their next Framework of between $50 and $200M. We have been proactive in building relationships with NVAC, the RVACs and European researchers who will contribute to the international effort in this area. This enables us to help to coordinate Canadian research with the broader international effort, as we are doing in our Visual Analytics Theme of the new Canadian Design Research Network NCE. Our focus on the cognitive science of interaction helps to build a two-way dialog between international visual analytics scientists and Canadian strengths in perceptual and cognitive science. Our goal in this is to motivate and inform a deeper level of scientific inquiry into applied problems to generate guidelines for development as well as formative and summative cognitive tests that are based on the actual goals of the system-- enhanced cognitive processing by individuals and communication between individuals to address complex “wicked” problems in the context of safety and security. This work will transfer to other areas of problem solving for better government policy, more competitive industry, and advancement of the knowledge industries in Canada.

Commercial success

We feel that the systems we will help to design have a high potential for commercial success based on their performance alone. This builds on long-term Canadian success in HCI in graphics (Alias, Wavefront, Softimage) and in collaborative technologies (RIM) as well as the unique skill set of our chosen partner companies. In addition to support for commercialization of innovation, our ability to leverage our role with NVAC enables us to provide early information about technology needs and contacts with potential US and European customers for our partner companies. We feel that our relationships will contribute to the strong business case of our partner companies as favoured technology providers as well as building an innovative university-industry research and development partnership.

Safety and Security

In addressing the theme of this Strategic CFP, we chose to concentrate on technologies to support flexible decision-making and communication between diverse stakeholders, e.g. in all 3 levels of government, relief agencies, health care, and emergency services. We base this on a firm conviction that the difficulty of anticipating the specific nature of all potential threats to safety and security (e.g. the 9/11 attacks) renders highly structured decision support environments of limited utility. It is critical that they be supplemented with a more flexible system that can support understanding and responding to new and evolving threat situations. This is a critical component of any comprehensive threat reduction effort. We also feel that our links to US and international efforts have direct benefit to support interoperability (an explicit goal of PARVAC) for international coordination (e.g. to maintain free flow of people and goods across the Canada/US border) and to support Canada-US relations through our contribution to collaborative research on problems of pressing importance for both countries.