UNIVERSITY OF MANITOBA

Proposed name of project:	**Estimated Total Project Costs:**
University of Manitoba 3D Control Testbed	$4,000,000

Designated Project Leader/Faculty/Dept: CV: x

Philip Ferguson

List Principal Users/Faculty/Dept:

1. Philip Ferguson, Faculty of Engineering, Dept. of Mechanical Engineering CV: x
2. Witold Kinsner, Faculty of Engineering, Dept. of Electrical Engineering CV: x
3. Cyrus Shafai, Faculty of Engineering, Dept. of Electrical Engineering CV: x
4. Dustin Isleifson, Faculty of Engineering, Centre for Earth Observation Science CV: x
5. Young-Jin Cha, Faculty of Engineering, Dept. of Civil Engineering CV: x
6. Eric Bibeau, Faculty of Engineering, Dept. of Mechanical Engineering CV: x

'Lead' Unit ADR/RLO:

Engineering

Name:

Cyrus Shafai

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Introduction

Many of today's innovative technologies require development and demonstration in a well-controlled three-dimensional environment. Spacecraft systems, drone-based infrastructure inspection, industry 4.0 robotics and advanced remote sensing all require precise three-dimensional control and tracking.

In the space industry, new control technologies traditionally require thousands of hours of simulations and demonstration missions costing hundreds of millions of dollars before technologies are certified for use in space. This barrier to entry means that encouraging technologies such as adaptive, non-linear and fractional controllers that promise to reduce the cost and design cycle time of space missions never make it into the space industry, leaving the space industry largely stagnated. An indoor three-dimensional testbed that enables drone operations with precise 3D position telemetry would support this research by enabling researchers to define a particular dynamic environment (microgravity, relative orbital dynamics, surface exploration in varying gravities and air densities, etc.) and then execute candidate controllers on representative space hardware. By using this hardware-in-the-loop testbed, researchers will be able to raise the technology readiness level of new satellite technologies without having to pay for expensive launches or microgravity research time (typically in parabolic flight). This same testbed would also be used to validate methodologies for drone inspection, drone-based remote sensing, collaborative exploration using a mix of flying and ground-based robots and even "Industry 4.0" robotics for advanced factories using Industrial Internet of Things (IIOT).

Proposed Collaboration Team

This project would provide a shared research environment to be used by Dr. Philip Ferguson (NSERC / Magellan Industrial Research Chair in Satellite Engineering and Associate Professor of Mechanical Engineering), Dr. Cyrus Shafai (Associate Dean of Engineering, Director of the Nano-Systems Fabrication Lab and Professor of Electrical Engineering), Dr. Witold Kinsner (Director of the Cognitive Systems Laboratory, Vice President of IEEE and Professor of Electrical and Computer Engineering), Dr. Dustin Isleifson (Assistant Professor in the Centre for Earth Observation Science), Dr. Young-Jin Cha (Assistant Professor of Civil Engineering) and Dr. Eric Bibeau (Associate Professor of Mechanical Engineering).

Proposed Research

Dr. Ferguson's spacecraft navigation and control research team will use this testbed to demonstrate 6-axis control during complex maneuvers such as those required to dock while in orbit around Lagrange points in the Earth-Moon system (required to support the Canadian Space Agency's exploration roadmap). Collaborations between Dr. Ferguson and Dr. Kinsner will extend this research to include exploration collaboration between orbiting spacecraft, drones and land-based rovers.

Dr. Kinsner also proposes to use this facility as a demonstration testbed for Industry 4.0 "internet of things" research based on machine learning and "fog computing". The 3D position measurement capability combined with high-fidelity video processing will enable research into automatic object classification, fault detection and preventative maintenance, in support of future manufacturing facilities based on the Industry 4.0 standard currently in development.

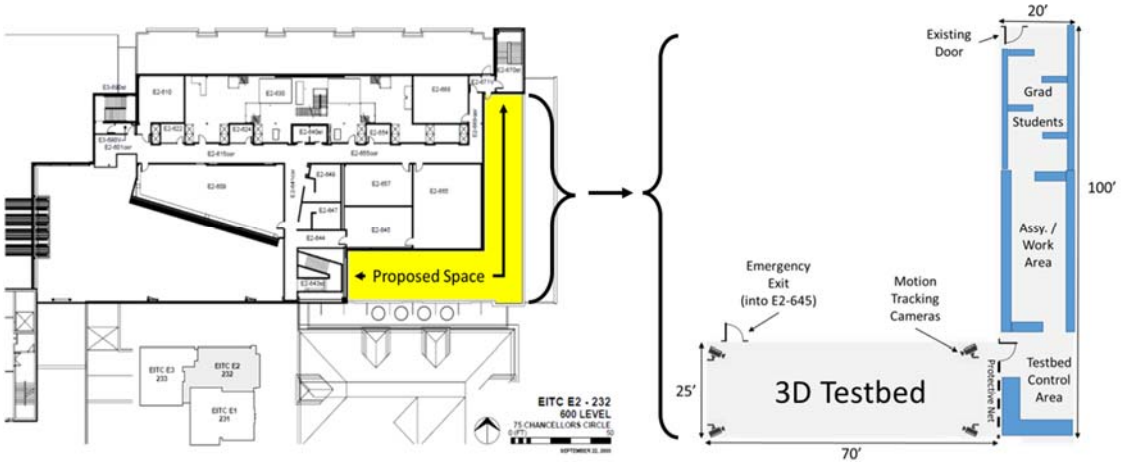
Dr. Cha's research focuses on the use of drones for structural inspection. Dr. Cha will use this facility to develop and demonstrate automatic bridge and building inspection using drones in a safe and controlled manner without requiring Transport Canada approval to fly outdoors.

Dr. Dustin Isleifson, Dr. Cyrus Shafai and Dr. Eric Bibeau work on remote sensing solutions that could

be implemented on drones for field deployment. These sensors require a facility with precise 3D position telemetry to support the drone integration and development of flight plans / processing algorithms to collect and interpret the data. Dr. Isleifson is currently collaborating with Dr. Ferguson on drone-based synthetic aperture radar sensors for monitoring arctic sea ice. Dr. Shafai is developing RF sensors in support of high-voltage infrastructure inspections by drones. Dr. Bibeau studies innovative renewable energy technologies that require detailed aerial measurements of river currents. This indoor 3D testbed will support all of these remote sensing research projects with state-of-the-art instrumentation and computational capacity.

Proposed Location and Layout

The 6th floor of E2-EITC has an "L-shaped" roof section that is currently un-occupied. The space measures almost 4,000 square feet. An enclosing structure around the space would create an area for the testbed itself, a small assembly / laboratory area and a large area to seat approximately 8-10 graduate students. Motion capture cameras by Vicon would be used to track the position of the vehicles, feeding them back to a central control station. The control station will feature a Matlab interface that will enable rapid deployment of new dynamic simulations and candidate controllers using RealTime Workshop. Real-time video and ground station instrumentation would also be included.



Impact

This facility will be the only one in Canada with this capability, and second only to MIT in North America. An indoor testbed like this would be a highly valuable facility for the faculty that would spawn numerous research options in the future. As industry grows to adapt to advances in machine learning, artificial intelligence and Industry 4.0, Canada requires the facilities to support advanced motion control research in three dimensions. With the space industry preparing to explore other planets and moons, we need testbeds that enable multi-vehicle cooperation. This particular testbed would fill a current void that is preventing impactful guidance, navigation and controls research from finding its way into the space industry, the drone industry, the remote sensing industry and the manufacturing industry.

Funding Plan

Potential sources for matching funds include vendor discounts, MicroPilot, Magellan Aerospace and Peytec (an Ontario-based IIoT company enabling Industry 4.0 with low-power factory positioning sensors). Ongoing maintenance and operation of this facility could become part of future NSERC research chair renewals such as Dr. Ferguson's current Industrial Research Chair.