Center for Multi-Scale Integrated Intelligent Interactive Sensing (MINTS)

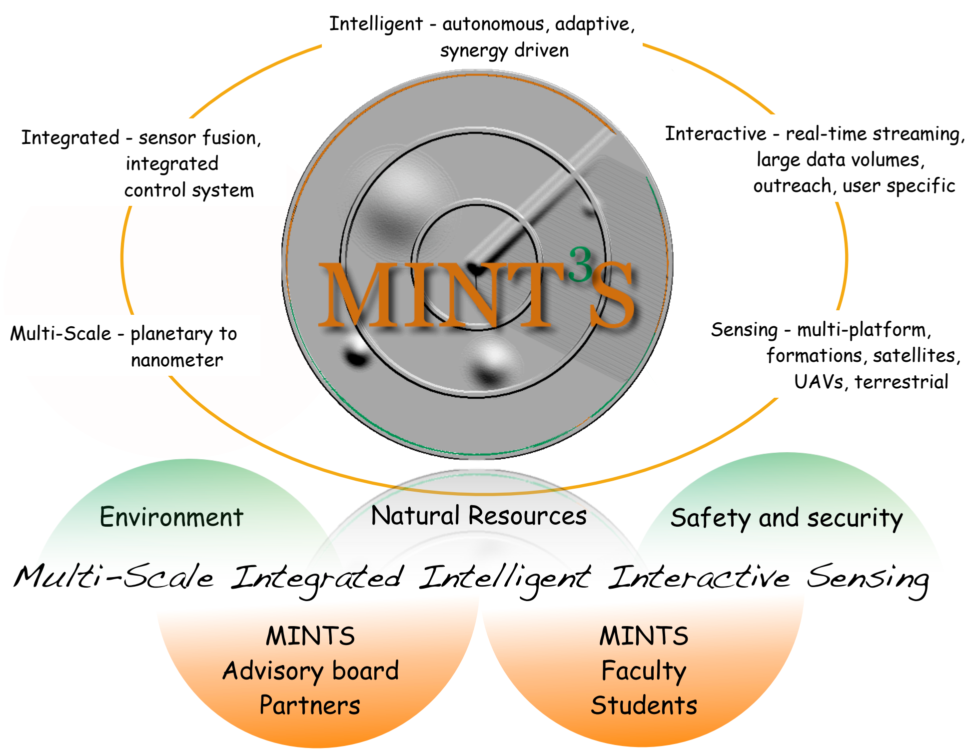
http://mints.utdallas.edu

Vision

In many areas of scientific research, a complete observational context, coupled with theory, is invaluable for an in-depth understanding. This context ideally involves integrating (i.e. fusing) observations of multiple parameters from multiple sensors on multiple spatial and temporal scales. Automatically acquiring such observations represents a major challenge. Employing intelligent and adaptive observation strategies that automatically focus on observing the parameters at the locations, times and scales with the highest information content can greatly facilitate acquiring an adequate observational characterization within tractable data volumes.

Remote sensing of the Earth and atmosphere traditionally relies on satellite platforms that provide a homogeneous and continuous coverage of the entire planet. However, the spatio-temporal resolution of satellite remote sensing is always inferior to airborne and terrestrial sensing platforms. In recent years, remote sensing from satellites has seen dramatic improvements in both accuracy and spatio-temporal resolution. More than ever, there is a need to close the gap between the satellite, airborne and terrestrial observations. To make best use of these improvements requires a comprehensive treatment of observation representativeness, calibration and validation. Ultimately, merging remote sensing observations on all scales is key to fully exploit the synergies and overcome the limitations of individual sensing techniques.

The vision of the Center for Multi-Scale Integrated Intelligent Interactive Sensing (MINTS) is a holistic intelligent synergy of integrated, targeted observations from multiple platforms on multiple spatial and temporal scales, together with state of the art compression and visualization systems for the distribution and comprehensive analysis of complete datasets. By combining instruments on satellites and robotic vehicles (in air, land, and sea) that can be directed in real time, we can capture observations on multiple parameters on multiple spatial and temporal scales appropriate to a wide range of problems. The schematic illustrates the MINTS approach to science and learning. Each element (i.e., “multi-scale”, “intelligent”, “integrated”, “interactive”, “sensing”) is, in fact, a novel component that is exploited to solve existing problems as described below.



Exploiting Synergies Through MINTS

Need for MINTS

Current methods involving integration of multiple sensors often approach data collection, processing, analysis, and data dissemination as separate problems. In fact, these are closely related problems, and optimization on one task can affect the others. Our aim is to simultaneously optimize these components by maximizing resolution, measurement accuracy, communication bandwidth, and computation performance. In particular, we address error characteristics, and we investigate how errors arise and propagate through the observational system and affect representativeness of observables. Furthermore, we seek to automate the sensing process, allowing intelligent, adaptive, self-directed sensors, algorithms and visualization. This is explained through each of the MINTS objectives, outlined in the following sections.

Multi-Scale

Many areas of scientific research encounter a contrasting set of needs. High frequency features and/or correlations may occur only over small spatial and/or time scales. Conversely, important features and correlations in data may occur over small or large spatial and/or time scales. This creates a host of problems with different solutions, particularly when a complete observational model and theory at multiple scales is needed for an in depth understanding. One solution is to capture a dense sampling in space and/or time over a large area/period. While this will capture both high and low frequency data, it is often infeasible to process this quantity of information. For example, a high definition video camera will generate 7 GB of data per minute. This amount of data cannot be processed or transmitted in a timely manner. Storage and visualization of this data can strain computer systems. Furthermore, it may simply be impossible to gather dense samplings over a large scale due to limitations on cost and the number of sensors.

Observations at multiple scales provide a solution. Intelligent and adaptive observation strategies can observe sparse data samplings and automatically concentrate on locations and times with the highest interest or information content. These targets (whether spatial or temporal) can be subject to sampling and analysis at a finer resolution. Alternately, simultaneous observations at multiple scales can be integrated (or fused) to provide an estimate of the system at all scales (e.g., consider satellite observations merged with lower altitude airborne and/or terrestrial-based observations). An optimal estimation requires an intelligent process to create a model of the system that can be adapted autonomously, as well as adaptive sensors that can be directed to the region of most valuable information content. Finally, if large-scale, high-resolution data sets are gathered, proper encoding algorithms must be found to accurately represent the data at any appropriate scale for specific transmission, processing or visualization. This scaling should automatically adjust for multiple users on platforms ranging from smart phones to high-end computers with high-speed internet.

INTelligent

The notion of intelligence in sensor networks often implies autonomy. That is, the sensor network is able to direct its own operation to collect and process appropriate data with little or no user intervention. At the sensor level, intelligent sensors are able to alter their operating parameters or location in order to acquire valuable data. This can be decentralized, with each sensor agent operating as it sees fit, or centralized with a controlling arbiter issuing commands to sensors. The key aspect is that human intervention is not necessary beyond initial inputs and periodic updates. The sensors can operate on individual spatial and temporal scales, and these scales figure into the operation.

At the output level, an intelligent sensor system can assimilate and compile data into the clearest, most concise representation for the user. This may take the form of a visual representation, which can be processed by a human much faster than textual information. Additionally, the intelligent system my be able to provide analysis and prediction of what the resulting data means, and predict what data the user will be most interested in. Operation at both the sensor level and output level must occur within the time constraints of the problem in order to facilitate real-time applications as well as post-processing options.

INTegrated

The integration, or fusion, of multiple, disparate sensor signals is essential to the MINTS mission. Sensors operating at different spatial resolutions and time scales must be integrated to provide a smooth, detailed estimation or representation of the system. Additionally, multiple sensor modalities observing the same system (e.g. sensing at multiple wavelength of light and small aperture radar) can be fused to produce estimates or data sets far richer than each sensor running independently. Existing system models or distribution priors can be leveraged to create more accurate fused systems through Kalman filters (and the various extensions) or Bayesian filters to reduce the effects of noise or sensor error.

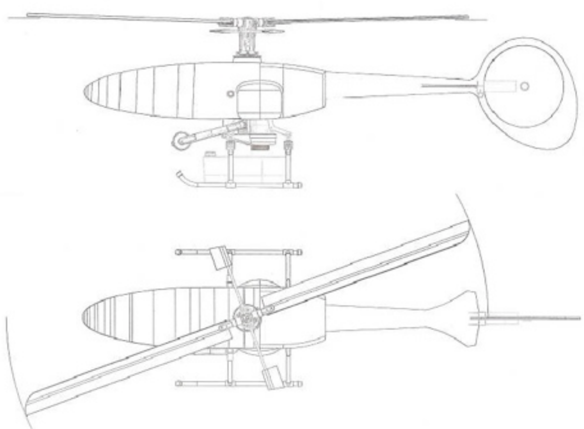
This will entail the creation of novel platforms that incorporate multiple sensors. This is exemplified by the current deployment of a robotic helicopter, which will include multiple cameras and an array of sensors. These include, a UV camera, a stereo pair of high resolution visible cameras (for recreating 3D terrain), an infrared camera that can provide temperature maps with 0.05°C resolution, meteorological sensors (temperature, pressure, humidity), a laser scanner for accurate 3D terrain mapping, an aerosol spectrometer giving fully size resolved spectra from 30 nm to 30 μm, a suite of laser based gas sensors for green house gases and pollutants. The MINTS focus on accuracy throughout the observation process will require novel calibration procedures to determine spatial and temporal offsets and parameter differences between sensors.

INTeractive

Continuing and accelerating the advancements in science and technology will require people to comprehend vast amounts of data and information produced from a multitude of sources. Interactive visualization, namely helping people explore or explain data through software systems that provide an interactive visual representation, will be critical in achieving this goal. Recent advances of computer graphics and visualization have created the ability to represent increasingly large datasets and have simultaneously introduced the ability for users to manipulate data interactively.

Human beings are biologically equipped to make spatial inferences and decisions. Interactive visualization can bootstrap this facility metaphorically, by mapping elements and spatial relations in the abstract domain onto elements and relations in a concrete visualization. Interactive visualization is useful for detecting patterns, assessing situations, and prioritizing tasks. The design of novel visualization algorithms (e.g. 3D navigation in virtual reality) for MINTS will help the end users to understand the observed phenomenon. Furthermore, it will lead to understanding the function of sensor networks for system managers to assess where new resources are needed. For certain applications in environmental management and geosciences, an innovative, interactive approach will relay key information between operators in the field and those in the lab or classroom setting.

The large volume of observation data acquired from high definition video camera (3D, stereo, or thermal images, etc.) poses grand challenges for interactive and efficient processing, transmission, and visualization of these data sets. The challenges come from both spatial and temporal complexities of the computing and visualization algorithms. Spatially, the data should be compact to support efficient storage and transmission between networked sites. Temporally, the compression, processing, and visualization algorithms should be executed in real-time so that the information can be fed back to the users in a timely fashion. High performance computation and visualization will be explored, such as the utilities of clusters of graphics processing units (GPUs) for both computing and visualizing such multi-scale observation data.



Sensing

Remote sensing comprises the science of observing a target without being in physical contact, hence, by definition, it is a multi-scale discipline. The sensing component of MINTS is targeted at developing and using platforms which enable sensing at multiple scales, from Earth orbiting satellites to nano-particle sensors on the ground. MINTS is particularly focused on closing observational gaps between the global and local scale in order to provide improved calibration/validation information for existing sensors, and to fill in spatio-temporal resolution data not covered by existing sensor systems. The sensing component of MINTS involves various (i) platforms, (ii) instruments/modalities, and (iii) validation/calibration.

The platforms that are utilized include space-based satellites, airborne aircrafts, unmanned autonomous helicopters, tethered or remote controlled blimps, terrestrial stations, marine vehicles and mobile robots. In particular, the helicopter, blimp and mobile robots are uniquely configured in-house at UT Dallas for MINTS applications.

Instruments used onboard the platforms shall be synergy-driven and will be designed based on the application at hand. Current sensors include still and video cameras, infrared and ultraviolet cameras, laser scanners (both airborne and terrestrial), GNSS receivers, vision-based control units, Inertial Navigation Units, and particle sensors.

The calibration and validation aspect of sensing is of utmost importance, as the variety of existing platforms and their specific resolution and accuracy specifications require diverse calibration/validation data of higher quality. However, higher quality can only be reached through exploitation of sensor synergies or by taking observations closer to the target. MINTS systems can be designed to provide this data at many scales. Establishing ground truth data is key to assess the representativeness of observations. Calibration/validation together with proper error assessment is key to achieve accurate standards and concrete deliverables.

APPLICATIONS

Environmental Science

The challenge: Man's impact on atmospheric composition has a broad range of societal ramifications. Today there are 22 million people in the US with asthma. One of the environmental triggers for asthma is airborne particulates. Rising greenhouse gas levels have been cause for considerable concern. Air quality and high levels of surface ozone and NO_x have deleterious health impacts. To objectively address each of these areas we need accurate observations. The observations are particularly valuable when they provide the big picture and local detail of spatial and temporal coverage. Providing accurate and comprehensive observations is a challenge. In-situ observations, such as those made by the EPA at roadside locations are expensive to make. In addition, there is always the issue of representativeness, i.e. how representative is a measurement made at an urban roadside site of the surrounding region.

Our approach: Because these issues are so important, and because there are several outstanding challenges, we have specialized in taking an alternative approach to addressing these issues. First, we employ an observation platform that can adequately sample the spatial variation of particulates, greenhouse gasses and pollutants, namely a robotic helicopter. Second, wherever possible, we use accurate absolute laser based observations. Third, we use a combination of satellite data and machine learning to provide the global context for the local observations.

What is new: To the best of our knowledge we are the first group internationally to do three things. First, we make observations of particle number-, surface-, and mass distributions from 30 nm to 30μm on a robotic helicopter platform. The robotic helicopter platform allows us to profile the particulate size distribution and examine the representativeness issues that are of significant importance in an urban setting. Nano-particles (particles < 0.1 μm in mass median aerodynamic diameter) have been postulated to affect cardiopulmonary systems, and are reportedly able to penetrate deeply into the respiratory tract and have a larger surface area per unit mass than do larger particles, thus resulting in a greater inflammatory response. Second, we use a robotic helicopter to simultaneously measure particulates, greenhouse gases and a suite of pollutants while using visible and thermal imaging of the earth surface. This surface imaging allows us to accurately characterize the surface topography and any local particulate and pollutant sources. Third, we use machine learning to both cross-calibrate multiple satellite datasets and to directly relate the satellite observations to in-situ observations.

Natural Resources and Energy

The Challenge: Natural resources and their exploitation ensures the livelihood of most economic centers in the world. Major discoveries are rarely made as the identification of new mineral deposits and hydrocarbon reservoirs are increasingly difficult. Energy generation and transportation of energy is critical to an ever increasing portion of the world's population. Thus, two key aspects are the support of locating and identifying natural resource parameters, and the mitigation of energy loss during transmission and avoidance of energy waste. Efficient and economic extraction and development of mineral resources is also possible.

Our approach: MINTS asks the question "Are there any physical indicators that help identify natural resources and energy transmission losses". Can MINTS measure them and provide feedback to industries, which could use this additional information? One example is presented by the gas reservoirs related to black shales, which are distributed worldwide. The detailed characterization of shale reservoirs has not been carried out commonly and is difficult, but crucial, for understanding and estimating gas content and permeability. MINTS is able to provide mm to cm-precise morphological information of shale outcrops, with efficiently detailed surrounding information to place the sites in context which in turn could be used to understand the degree of fracture in the shales as well as permeability. In addition, related terrain, geochemical, and geologic information can be integrated with the particular sites. MINTS can also measure mass transfer from and into hydrocarbon and water reservoirs with the highest accuracy gravity instruments available today.

What's new: Instead of trying to observe and monitor the needed parameter directly (e.g. oil content in a formation) MINTS aims at providing indirect measurements of secondary parameters that can be fused with primary parameters to improve our understanding of Earth systems, e.g. reservoirs and deposits. New discoveries rely on small incremental improvements, which are often overlooked. MINTS will approach these subtle parameters and their change in time and space to better characterize the Earth system.

Agriculture

The challenge: Quantifying crop or livestock health and natural variability in a timely manner is critical to both agricultural sustainability and profitability. The large spatial scales involved for crop lands and the size of livestock herds demonstrate the magnitude of this task . For example, eight million cows, a quarter of the entire US cattle population, live within 150 miles of Amarillo, TX . Given that a typical beef cattle feeding lot may accommodate 50,000 cattle, with a staff of around ten people, acquiring timely, detailed information on the health of the herd is a daunting task.

Our approach: We fly an unmanned helicopter over the crops or livestock. This helicopter is equipped with accurate GPS and a suite of sensors including accurate thermal and multispectral imaging, and laser scanning enabling rapid acquisition of detailed information on critical metrics such as canopy/crop height, crop or heard health (e.g. if any animals have a fever), herd morphology, and feeding lot soiling. In addition, as the helicopter also contains a comprehensive suite of air composition measurements for particulates, green house gases and pollutants, we can simultaneously map atmospheric composition, valuable for the addressing EPA compliance issues.

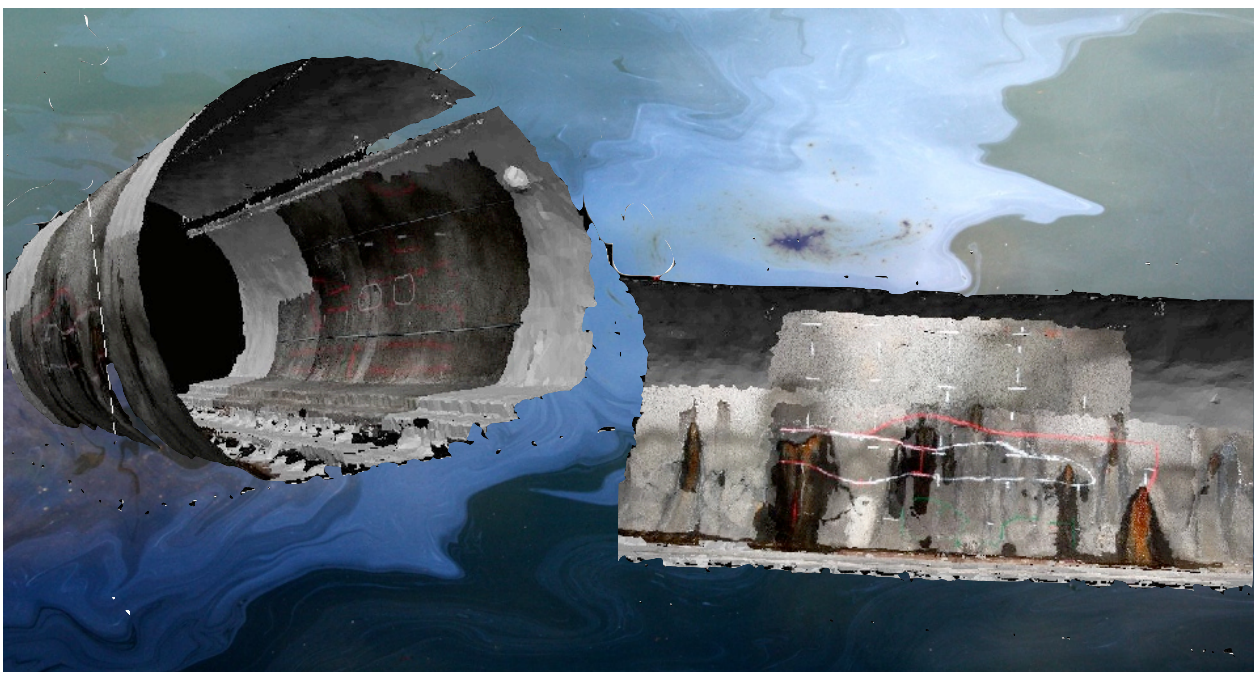
What is new: To the best of our knowledge we are the first group internationally to make simultaneous observations from a robotic helicopter addressing atmospheric composition, detailed terrain (including canopy/crop height, individual animal morphology, feeding lot soiling depth), and thermal imaging (e.g. detecting any livestock fever) in a fully autonomous manner.

Safety, Security and Monitoring

The Challenge: Global travel has become standard in most industrial nations. International trade has flourished, and the demand for shipping and transportation of goods across the globe has increased dramatically. Goods are transported by ship, aircrafts or trucks, and national borders have minor impact on global trade. In addition, there is an increase in multi-national infrastructure projects spanning continents, e.g. oil & gas pipeline, power transmission lines, natural resources exploration. With this globalization comes a need for monitoring activities related to these global networks. Safety of transportation routes and infrastructure must be ensured to not compromise trade relationships. Moreover, the remoteness of some of these activities, e.g. pipelines in Alaska, shipping across the Pacific or Northwest Passage, airspace surveillance etc., demand a monitoring effort to ensure that the activities do not pose a risk to society. Undiscovered oil spills, pipeline leaks, chemical plumes, immobile ships etc., can develop environmental disasters if mitigation efforts are not put in place immediately.

Our approach: Once a security risk has been identified, a sensing system can be developed which monitors the target status. As soon as irregularities occur, the automated system can be supported by additional surveillance. The identification of changes in the physical parameters of a target is key to maintain safe operation and security for the environment and society. For instance, pipelines stretch over distances of several thousand miles and mostly cover remote areas. Leaks in high-pressure gas pipelines can both lead to further damage to the infrastructure or damage to the surrounding area. A robotic platform patrolling the pipeline using a thermal camera integrated with positioning unit and real-time data streaming would be able to mitigate the aforementioned risks.

What is new?: MINTS aims at providing solutions which are not only applicable to the problem at hand, e.g. monitoring a pipeline for leaks, but which are applicable in a much more general way for multiple other applications, e.g. thermal leaks in buildings. MINTS solutions try to optimize the sensing problem, so that with minor modifications it can be applied to other projects. This approach ensures that research and development are the major drivers and not the development and marketing of one specific solution for a specific application and market. MINTS targets optimization in resolution, accuracy, and efficiency through sensor fusion, control system integration and intelligent sensing.



OUTREACH

Keynote Speakers

An annual keynote speaker series will run throughout the academic year with invited speakers who are renowned in their field of expertise. This will be a jointly sponsored event from each participating department. The first series is scheduled to start in the Spring 2011 term with two distinguished speakers per term. The main purpose of the keynote speaker series is to provide the university (students, staff and faculty) and the general public an opportunity participate in an informative event that showcases the MINTS vision and current application areas and involves our collaborators and colleagues from across the globe. Details on upcoming speakers and more about MINTS can be found at http://mints.udallas.edu.

Advisory Board

An active and effective external advisory board is key to MINTS success. A preliminary list of members is:

Accepted Members

1. Garry Ackerman - Innovations Advocate, Raytheon Company, Space and Airborne Systems, Office of Innovation, Dallas, TX.
2. Pat O'Conell, Cargill Cattle Feeders, Lockney TX.
3. York Eggleston, CEO, Semantic Labs, Baltimore, MD
4. Lionel White, President, Geological & Historical VIrtual Models LLC, Dallas, TX

Team Expertise

The six founding members of MINTS are: David Lary (Physics), Alexander Braun (Geophysics), Georgia Fotopoulos (Geomatics Engineering), Nick Gans (Electrical Engineering), Xiaohou Guo (Computer Science) and Carlos Aiken (Geosciences).

David Lary completed his education in the United Kingdom. He received a First Class Double Honors B.Sc. in Physics and Chemistry from King's College London (1987) with the Sambrooke Exhibition Prize in Natural Science, and a Ph.D. in Atmospheric Chemistry from the University of Cambridge, Churchill College (1991). His thesis described the first chemical scheme for the ECMWF numerical weather prediction model. David then held post-doctoral research assistant and associate positions at Cambridge University until receiving a Royal Society University Research Fellowship in 1996 (also at Cambridge). From 1998 to 2000 David held a joint position at Cambridge and the University of Tel-Aviv as a senior lecturer and Alon fellow. In 2000 the chief scientific adviser to the British Prime Minister and Head of the British Office of Science and Technology, Professor Sir David King, recommended David to be appointed as a Cambridge University lecturer in Chemical Informatics. In 2001 David joined UMBC/GEST as the first distinguished Goddard fellow in earth science at the invitation of Richard Rood. His automatic code generation software, AutoChem, has received five NASA awards and has been recommended for the NASA Software of the Year Award. David is currently involved with NASA Aura validation using probability distribution functions and chemical data assimilation, neural networks for accelerating atmospheric models, the use of Earth Observing data for health and policy applications, and the optimal design of Earth Observing Systems. The thread running through all the research is the use of observation and automation to facilitate scientific discovery. His application of machine learning to bias detection and proxy inference led to the creation of the first global seamless record of atmospheric chlorine and received recognition as a NASA Aura mission science highlight, was selected as NASA GSFC Atmospheric Chemistry and Dynamics Branch selected publication, and a JCET science highlight. In 2010 David joined the Hanson Center for Space Science at the University of Texas at Dallas. David has received three prestigious fellowships, five editorial commendations, around five million dollars in research funding, six NASA awards, and has eighty-two publications with over a thousand citations in the peer-reviewed literature with a Hirsch Index of seventeen and on average 20 citations per publication.

Alexander Braun is a geophysicist and currently an Associate Professor in the Department of Geosciences at the University of Texas at Dallas. He received both Diploma (1995) and Dr. phil. nat. (1999) in geophysics from the Johann Wolfgang Goethe Universitaet Frankfurt, Germany. His two theses were on theoretical seismology of surface waves in heterogeneous media and geodynamic modeling and satellite derived gravity in the Norwegian shelf. He spent 3.5 years working for the GeoForschungsZentrum Potsdam on satellite mission development and operations, before he became a Byrd Fellow in the Byrd Polar Research Center of the Ohio State University. In 2004, he accepted a position as Assistant Professor in the Department of Geomatics Engineering of the University of Calgary, where he was promoted to Associate Professor in 2006. During the 5 years in Calgary, he worked on satellite altimetry, geodynamics, sea level and sea ice change and glacial isostatic adjustment.He won two teaching excellence awards and the early research excellence award in the Schulich School of Engineering. Since January 2010, he is with the University of Texas at Dallas. His research focus is on satellite monitoring of Earth system dynamics and its geophysical interpretation. His research group also employs Synthetic Aperture Radar, absolute gravimetry, terrestrial Lidar and laser altimetry. Throughout his academic career, he started 3 spin-off companies, and one is currently active. He has an interest in high performance computing and 4-D visualization of large data sets. He published 42 peer-reviewed publications, 30 of them in peer-reviewed journals, and gave 22 invited presentations. Scopus reports 118 citations and a Hirsch index of 7. Current affiliations include Research Associate with the Arctic Institute of North America, steering committee of the International Altimetry Service, and member of the Institute of Infrastructural Renewal and Reconstuction, AGU, EGU and Sound Science Initiative.

Georgia Fotopoulos received a BSc. (with distinction) in Geomatics Engineering from the University of Calgary in 1998, where she went on to complete a MSc. with a specialization in satellite positioning and navigation entitled ‘Parameterizaiton of DGPS carrier phase errors over a regional network of reference stations’ and a PhD in geodesy and geodynamics entitled ‘An analysis on the optimal combination of geoid, orthometric and ellipsoidal height data’ in 2003. During her PhD she was a visiting researcher at the University of New South Whales and Curtin University, Australia. In 2004, she received the prestigious Alberta Ingenuity Post Doctoral Fellowship where she spent a year as a visiting researcher at the Aristotle University of Thessaloniki in the Department of Geodesy and Surveying. In 2006 she joined the University of Toronto in the Department of Civil Engineering as an Assistant Professor and principal investigator of the Lassonde Institute for Engineering Geoscience. Her current position is at the University of Texas at Dallas in the Department of Geosciences as an Associate Professor. Her research interests include physical and satellite geodesy, satellite positioning and navigation, remote sensing for geoengineering and geoscience applications as well as algorithm development for microsatellite platforms. Throughout her academic studies and career Georgia has received over 25 scholarships and awards (since 2000), she has published extensively in peer reviewed journals and has a number of invited presentations at international conferences. Currently she is an (associate) editor of 3 journals, namely the Journal of Surveying Engineering, Geomatica, and the Journal of Geodetic Science. She is also an active member of the International Association of Geodesy and the Federation Internationale des Geometres.

Nick Gans received his B.S. degree in electrical engineering from Case Western Reserve University in 1999. He earned his M.S. in electrical and computer engineering and his Ph.D. in systems and entrepreneurial engineering from the University of Illinois at Urbana-Champaign in December 2005. Prior to joining UT Dallas, he worked as a postdoctoral researcher with the Mechanical and Aerospace Engineering Department at the University of Florida and as a postdoctoral associate with the National Research Council, where he conducted research on control of autonomous aircraft for the Air Force Research Laboratory and developed the Visualization Laboratory for simulation of vision-based control systems. Nick’s research interests include nonlinear and adaptive control, with focus on vision-based control and estimation, robotics and autonomous vehicles. Areas of particular interest include multivehicle control tasks such as platoons and swarms of vehicles. His recent efforts focus on mobile sensor networks that seek maximize the accuracy and value of information for various estimation schemes. He is also interested in developing visualization and virtual reality platforms for accurate simulation of vision-based controllers. Nicholas Gans brings expertise in machine vision and vision-based control, along with a background in robotics and nonlinear and adaptive control. He will develop vision-based object recognition and robot navigation tasks, and will work with other controls experts in this program to develop object grasp and manipulation algorithms. His facilities include mobile robots and robot manipulators capable of torque level control.

Xiaohu Guo is an assistant professor of computer science at University of Texas at Dallas. He received his B.S. degree in computer science from University of Science and Technology of China in 2001. He earned his M.S. and Ph.D. in computer science from the State University of New York at Stony Brook in May 2006. Xiaohu's research interests include computer graphics and visualization, with focus on geometric modeling and processing, physics-based simulation, and GPU-based computation. Areas of particular interest include (1) spectral geometry analysis for 3D compression, watermarking, mapping, and deformation; (2) Voronoi tessellation on parameterized manifold surfaces; (3) medical image analysis such as the 3D modeling of organ deformations and tracking of tumors; (4) tele-immersion system based on efficient GPU-assisted stereo reconstruction and streaming. He is also interested in developing virtual reality platforms for various applications in robotics and gaming. His researches are currently supported by several grants from National Science Foundation.

Carlos Aiken received his BS and MS in geology from the University of Washington in 1965 and 1970 and his PhD in Geological Sciences (geophysics) from the University of Arizona in 1976. He has taught at Texas Christian University 1975-1978 and at the University of Texas at Dallas since 1978, presently a Full Professor supervising the Cybermapping Laboratory in the Department of Geosciences. He is involved as a faculty in the Geospatial Information Sciences Program in teaching courses and supervising graduate students. In addition he is collaborating with the Arts and Technology Program in the Arts and Sciences School sharing undergraduate and graduate students , software and methodologies. As a geophysicist he worked in gravity and magnetics in exploration for minerals and petroleum and geothermal resources with companies as a consultant and contractor, as well as in geotechnical and solid earth studies for over 40 years publishing numerous papers and being funded by such organizations. In the Greenland Big G (gravitational constant) experiment in 1987 Aiken became involved with GPS for positioning for gravity and then later laser rangefinders for mapping detailed terrain for gravity terrain corrections. This technology was also then applied to mapping geology which led to developing the use over the last 10 years of digital cameras for capturing the real texture surfaces of geology with cameras (the photorealistic "virtual" 3D model) and was granted a patent on "Method and Apparatus for 3D Feature Mapping" in 2003. The main application has been for petroleum reservoir characterization using reservoir analogs or the actual rock exposures to better understand the important reservoir parameters and for training company geologists and petroleum engineers. An early model was of Mt. Rushmore Memorial and he has a screen credit for special effects of Mt. Rushmore scenes using his virtual model for a CBS TV mini series, in 2005 (Category 7: End of the World). He has put together a team developing workflows for 3D photorealistic geology mapping emphasizing mesh surfaces instead of just laser point clouds, which is unique, more accurate, with higher resolution but more efficient and expeditious. He has participated in digitally mapping many areas in the world including China, Europe, Greenland, New Zealand, Mexico, Central and South America and Canada funded by oil companies, universities and the National Science Foundation (recently one for building 3D photorealistic "virtual" models using laser scanners, digital photography and satellite positioning for use in undergraduate teaching and the other to build a national center for use of laser scanners and virtual modeling in academia which is the INTERFACE Project). Training and development was carried out for faculty and students by several universities using Terrestrial Laser Scanning software and workflows developed at UTD. Presently he is modeling the results of mapping two outcrops which are the largest he has ever done at the highest accuracy and resolution ever carried out to provide virtual models for reservoir characterization and to use as virtual models for their new geology training facility integrated with available surface and subsurface information. He is developing methods so that this unique 3D virtual modeling can be used for teaching geology at the undergraduate level. 3D GIIVE (3-Dimensional Geologic Interactive Information for Visualization in Education) is his program to apply virtual modeling in undergraduate education and is collaborating with the NSF funded Dallas STEM Gateways Collaborative and several community colleges. The educational initiative includes using a series of virtual outcrops across the Arbuckle Anticline in Oklahoma (cooperating with the Oklahoma Geological Survey and US Geological Survey) and several rock outcrops in the Dallas/north Texas area. These are being integrated with complementary local and regional digital geoscientific information to provide a total 3D approach in geologic research and education which will include an effective utilization of iPads and digital tablets to allow students and researchers to effectively interact with these digital data sets in the field and in the classroom.

With the Dept. of Geosciences and the collaborating UNAVCO Inc. he has access to considerable GNSS (Global Navigation Satellite Systems) receivers, terrestrial laser scanning and survey instruments, 3D visualization TVs and projectors, field computers and desktop computers. Software for these activities are also available and new software being written at UTD.