

# Industry Usage

Organization	Date	Accomplishment and Impact
Aalto University	2016	<a href="http://www.sciencedirect.com/science/article/pii/S0094576515004750">http://www.sciencedirect.com/science/article/pii/S0094576515004750</a>
University of Kufa	2015	<b>Reference:</b> Mahdi, Mohammed Chessab, "Orbit Design and Simulation for Kufasat Nanosatellite", Artificial Satellites. Volume 50, Issue 4, Pages 157–168, ISSN (Online) 2083-6104, DOI: <a href="https://doi.org/10.1515/arsa-2015-0013">10.1515/arsa-2015-0013</a> , December 2015
University of Arizona	2015	<b>Reference:</b> Kidd, John N., Jr., "Development and optimization of low energy orbits for advancing exploration of the solar system," Masters Thesis, <a href="http://gradworks.umi.com/15/90/1590327.html">http://gradworks.umi.com/15/90/1590327.html</a> .
University of Minnesota	2007	<b>Accomplishments:</b> GMAT is used to help design low altitude polar lunar frozen orbits (Semrud, D., "Low Altitude Polar Lunar Frozen Orbits," Intern presentation, <a href="http://www.aem.umn.edu/info/spotlight/interns07/Semrud_final.pdf">http://www.aem.umn.edu/info/spotlight/interns07/Semrud_final.pdf</a> ) <b>Impact:</b> Lunar frozen orbits are an orbit type that can yield the longest lifetime and still maintain a safe altitude above the lunar mountains.
DCM Research Resources LLC	2009	<b>Accomplishments:</b> Results of a space situational awareness study were demonstrated using GMAT. (Chen, G., et. al., "Awareness-Based Game-Theoretic Space Resource Management," Sensors and Systems for Space Applications III, edited by Joseph L. Cox, Pejmun Motaghedi, Proc. of SPIE Vol. 7330, 73300P) <b>Impact:</b> GMAT used as part of a simulation platform for a space situational awareness study.
DCM Research Resources LLC, AFRL, University of New Orleans	2009	<b>Accomplishments:</b> GMAT is used to test algorithms used to aid automatic decision making and to improve the effectiveness and robustness of space surveillance. GMAT was used in a user interface capability as the system controller as well as the visualization tool in this simulation study. (Chen, G., et. al., "Multi-agent modeling and analysis for space situation awareness," SPIE, 2009) <b>Impact:</b> GMAT was used to help improve the nation's space situational awareness capability.
University of California	2010	<b>Accomplishments:</b> GMAT is one of the mission design and navigation tools used for the THEMIS mission. "THEMIS – a five-spacecraft constellation – is a NASA Medium Explorer mission that was launched in 2007 and maneuvered into synchronized, highly elliptical Earth orbits to study magnetospheric physics leading to the appearance of the aurora borealis." (Bester, M., et. al., "Operations Planning and Mission Readiness Testing for the THEMIS Spacecraft Constellation," IEEEAC paper #1408, IEEE, 2010) <b>Impact:</b> GMAT is one of the tools used to help a university operate a five-spacecraft constellation.
University of New Orleans	2010	<b>Accomplishments:</b> Nonlinear filtering techniques developed for tracking a space object with possibly delayed measurements were demonstrated using GMAT. (Chen, H., et. al., "Space Object Tracking with Delayed Measurements," Space Missions and Technologies, edited by Joseph Lee Cox, Manfred G. Bester, Wolfgang Fink, Proc. of SPIE Vol. 7691, 76910J) <b>Impact:</b> GMAT used as part of a simulation platform to analyze a space object tracking method.
University of Colorado	2010	<b>Accomplishments:</b> GMAT was used to help demonstrate the validity of a science targeting scheme for a proposed flagship mission. A star target selection scheme for the proposed New Worlds Observer mission, a libration point orbit mission whose goal is to image planets within the habitable zones of stars beyond our solar system, was developed. (Cheetham, B., et. al., "INVESTIGATION OF TARGET SELECTION SCHEMES FOR A SPACE TELESCOPE-OCCULTER SYSTEM IN THE SUN-EARTH L2 REGIME," AAS 10-165, Advances in the Astronautical Sciences Volume 136, 2010) <b>Impact:</b> GMAT used to validate a science targeting scheme.

<p><b>Independent consultant,</b></p> <p><b>AFRL</b></p>	<p>2011</p>	<p><b>Accomplishments:</b> A pursuit-evasion orbital game approach for satellite interception and collision avoidance is simulated using GMAT.</p> <p>(Shen, D., et. al., "Pursuit-Evasion Orbital Game for Satellite Interception and Collision Avoidance," Sensors and Systems for Space Applications IV, edited by Khanh D. Pham, Henry Zmuda, Joseph Lee Cox, Greg J. Meyer, Proc. of SPIE Vol. 8044, 80440B)</p> <p><b>Impact:</b> GMAT used as part of a simulation platform to analyze a satellite interception and collision avoidance study.</p>
<p><b>Iowa State University</b></p>	<p>2011</p>	<p><b>Accomplishments:</b> GMAT was used as part of an asteroid impact study. High-energy nuclear disruption/fragmentation is an option for mitigating the most probable impact threat of near-Earth objects (NEOs) with a short warning time. GMAT is one of three tools used to precisely calculate the trajectory of many fragmented bodies in order to calculate collision probabilities.</p> <p>(Pitz, A., et. al., "EARTH-IMPACT PROBABILITY COMPUTATION OF DISRUPTED ASTEROID FRAGMENTS USING GMAT/STK/CODES," AAS 11-408)</p> <p><b>Impact:</b> This research will be used to help produce a "robust software system for assessing the consequence of a high-energy nuclear disruption mission for mitigating the impact threat of hazardous NEOs."</p>
<p><b>Independent Consultant,</b></p> <p><b>AFRL</b></p>	<p>2011</p>	<p><b>Accomplishments:</b> GMAT is used to build a simulator to test a trust-based sensor allocation algorithm.</p> <p>(Shen, D., et. al., "A Trust-based Sensor Allocation Algorithm in Cooperative Space Search Problems," Sensors and Systems for Space Applications IV, edited by Khanh D. Pham, Henry Zmuda, Joseph Lee Cox, Greg J. Meyer, Proc. of SPIE Vol. 8044, 80440C, 2011)</p> <p><b>Impact:</b> GMAT used to help test an algorithm used to solve the space search problem.</p>
<p><b>Texas A&amp;M University</b></p>	<p>2011</p>	<p><b>Accomplishments:</b> A MMS formation optimization method, in the presence of formation initialization errors, was verified using GMAT.</p> <p>(Roscoe, C., W., T., et. al., "Optimal Formation Design for Magnetospheric Multiscale Mission Using Differential Orbital Elements," <i>Journal of Guidance, Control, and Dynamics</i>, Vol. 34, No. 4, July–August 2011, pp. 1070-1080.)</p> <p><b>Impact:</b> The MMS project has access to additional validated formation optimization methods.</p>
<p><b>Beihang University,</b></p> <p><b>Beijing, China</b></p>	<p>2012</p>	<p><b>Accomplishments:</b> A spacecraft attitude and orbit simulation platform using matlab/simulink, and imported C/Fortran code is developed and its sample use for a Chinese weather satellite is described. GMAT is used to test the orbit propagations for this new simulator platform.</p> <p>(Hongzheng, C., et. al., "High Precision and Convenient Extension Simulation Platform for Satellite Attitude and Orbit System," Fourth International Conference on Machine Vision (ICMV 2011): Machine Vision, Image Processing, and Pattern Analysis, edited by Zhu Zeng, Yuting Li, Proc. of SPIE Vol. 8349, 83491O, 2012.)</p> <p><b>Impact:</b> GMAT helped verify the design of a new simulation platform.</p>
<p><b>European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)</b></p>	<p>2012</p>	<p><b>Accomplishments:</b> EUMETSAT used GMAT to perform a mission design study for their proposed next generation of polar weather satellites. EUMETSAT currently operates a fleet of weather satellites in both polar and geostationary orbits. A further description of the EUMETSAT mission is given on their website (<a href="http://www.eumetsat.int/">http://www.eumetsat.int/</a>):</p> <p><i>We operate a system of meteorological satellites that observe the atmosphere and ocean and land surfaces – 24 hours a day, 365 days a year. This data is supplied to the National Meteorological Services of the organisation's Member and Cooperating States in Europe, as well as other users worldwide.</i></p> <p><i>The service provided by EUMETSAT helps to enhance and safeguard the daily lives of European citizens. They aid meteorologists in identifying and monitoring the development of potentially dangerous weather situations and in issuing timely forecasts and warnings to emergency services and local authorities, helping to mitigate the effects of severe weather and protecting human life and property.</i></p> <p><i>This information is also critical to the safety of air travel, shipping and road traffic, and to the daily business of farming, construction and many other industries.</i></p> <p>EUMETSAT used GMAT, coupled with some matlab tools they developed, to perform a Timeliness study for their proposed new fleet of polar satellites, the EUMETSAT Polar System Second Generation (EPS-SG), to be deployed in the 2021 time frame. Timeliness is defined as the time between when an observation is made and when the end data product is available to the user.</p> <p><b>Impact:</b> GMAT helped a major international intergovernmental organization perform a mission design study for their next generation of polar weather satellites.</p>

<b>Texas A&amp;M University</b>	2012	<p><b>Accomplishments:</b> An analytical method, analyzing the effect of third-body perturbations on satellite formations, is applied to the MMS mission. GMAT is used to simulate the results.</p> <p>(Koblick, D., et. al., "THIRD-BODY PERTURBATION EFFECTS ON SATELLITE FORMATIONS," AAS 12-631, Jer-Nan Juang Astrodynamics Symposium, College Station, Texas, June 24 - 26, 2012.)</p> <p><b>Impact:</b> An analytical orbit perturbation method, applied to MMS, is verified using GMAT.</p>
<b>Pratt &amp; Whitney Rocketdyne</b>	2012	<p><b>Accomplishments:</b> GMAT was one of four tools used to perform a detailed solar electric propulsion study which analyzed various propellant options for three sample missions. GMAT was used for relatively high fidelity mission point designs and trajectory analysis verification as well as trajectory visualization.</p> <p>(Kokan, Joyner II, C., "Mission Comparison of Hall Effect and Gridded Ion Thrusters Utilizing Various Propellant Options," AIAA 2012-5237, AIAA SPACE 2012 Conference &amp; Exposition, 11 - 13 September 2012, Pasadena, California)</p> <p><b>Impact:</b> GMAT used to help verify some results of a solar electric propulsion study.</p>
<b>Purdue University</b>	2013	<p><b>Accomplishments:</b> Earth-Moon trajectories, developed using Adaptive Trajectory Design techniques, were verified and refined, using high fidelity force modeling, using GMAT.</p> <p>(Haapala, A., et. al., "TRAJECTORY SELECTION STRATEGY FOR TOURS IN THE EARTH-MOON SYSTEM," AAS 13-782, xxx.)</p> <p><b>Impact:</b> GMAT used to verify and refine a Earth-moon trajectory.</p>
<b>University of Colorado</b>	2013	<p><b>Accomplishments:</b> An analytical method is used to find geosynchronous disposal orbits where the solar radiation pressure induced eccentricity perturbation is minimized. GMAT is used to evaluate the evolution of these supersynchronous disposal orbits using a higher fidelity force model.</p> <p>(Jones, S., Negating the Yearly Eccentricity Magnitude Variation of Super-synchronous Disposal Orbits due to Solar Radiation Pressure," Masters thesis, University of Colorado, 2013 )</p> <p><b>Impact:</b> GMAT is used to evaluate new possible geosynchronous disposal orbits.</p>
<b>a.i. solutions</b>	2013	<p><b>Accomplishments:</b> Collision avoidance calculations involving space objects are very computationally intensive. This paper analyzes the use Graphical Processing Units (GPU) to greatly accelerate these calculations. GMAT was one of the tools used to test this new methodology.</p> <p>(Brown, A., et. al., "Conceptual System Design of a Solar Electric Propulsion Stage for Earth-Moon Cargo Transfer Missions," AAS 13-902, ADVANCES IN THE ASTRONAUTICAL SCIENCES ASTRODYNAMICS 2013 (2014), Volume 150, AAS/AIAA Astrodynamics Specialist Conference, August 11–15, 2013.)</p> <p><b>Impact:</b> GMAT used to help test a method used to greatly increase the speed of collision avoidance calculations thus allowing these calculations to be performed with increased fidelity.</p>
<b>Delft University of Technology, Delft, The Netherlands</b>	2013	<p><b>Accomplishments:</b> This thesis develops a conceptual design for a Solar Electric Propulsion (SEP) stage for Earth-Moon cargo transfer missions. GMAT is used extensively to verify trajectories obtained from the mission analysis program used in this study.</p> <p>(Bos, R., et. al., "Conceptual System Design of a Solar Electric Propulsion Stage for Earth-Moon Cargo Transfer Missions," Masters Thesis, Delft University of Technology, January 17, 2013.)</p> <p><b>Impact:</b> GMAT is used to verify SEP Earth-Moon transfer trajectories.</p>
<b>University of Colorado, Boulder</b>	2013	<p><b>Accomplishments:</b> GMAT was used to perform a sanity check on some of the propagations used in an orbital debris study in the geostationary orbit regime.</p> <p>(Anderson, P., V., Schaub, H., "Local orbital debris flux study in the geostationary ring," Advances in Space Research 51, 2013, pp. 2195–2206.)</p> <p><b>Impact:</b> GMAT used to help verify orbital debris study.</p>
<b>Tartu Observatory, Estonia,</b>  <b>University of Applied Science Aachen, Germany,</b>  <b>NanoSpace AB, Sweden</b>	2014	<p><b>Accomplishments:</b> The design for a micro-electromechanical systems (MEMS) technology based miniaturized cold gas propulsion module for cubesat type missions is presented. GMAT is used to simulate a number of low earth orbit mission scenarios: natural deorbiting, orbit raising and lowering maneuvers, and station-keeping.</p> <p>(Kvell, U., et. al., "Nanosatellite orbit control using MEMS cold gas thrusters," Proceedings of the Estonian Academy of Sciences, 2014, 63, 2S, 279–285, 2014)</p> <p><b>Impact:</b> GMAT is used as a software simulation platform to test a new propulsion module design.</p>

<p><b>University of Stuttgart, Germany</b></p>	<p>2014</p>	<p><b>Accomplishments:</b> As part of an international student design competition organized by the Mars Society in collaboration with Dennis Tito's Inspiration Mars Initiative, the University of Stuttgart team designed a Mars flyby mission concept. The final trajectory obtained as part of this concept was verified using GMAT.</p> <p>(Fries, D., et. al., Mission Design of a Two-Person Mars Flyby by 2018," 2014 Mars Society Convention, Houston, Texas, August 9, 2014.)</p> <p><b>Impact:</b> GMAT is used to verify the final Mars flyby trajectory (with a return to Earth) generated as part of an international student design competition.</p>
<p><b>University of California</b></p>	<p>2014</p>	<p><b>Accomplishments:</b> Goddard used GMAT to help design and optimize the ARTEMIS trajectories. As the operator of the two ARTEMIS probes, the University of California needed to exchange mission data with Goddard. ARTEMIS is an extension mission, using two of the five THEMIS spacecraft, that studied the lunar environment.</p> <p>(Bester, M., et. al., "ARTEMIS Operations – Experiences and Lessons Learned," IEEE, 2014)</p> <p><b>Impact:</b> GMAT is used to design and optimize the ARTEMIS extension mission. As part of this effort, the University of California built a software interface to GMAT to improve the communication of mission design and navigation data between the university and NASA Goddard.</p>
<p><b>KinetX, Inc., Space Research Institute of Russian Academy of Science, Moscow Institute of Electronics and Mathematics, University of Arizona</b></p>	<p>2014</p>	<p><b>Accomplishments:</b> GMAT was used to verify some complex trajectories to Near-Earth Objects (NEOs). An example trajectory is a one-year return to a NEO that starts from an Earth-Moon L2 Halo orbit, uses three lunar swingbys and relatively small propulsive maneuvers to flyby an asteroid and then return to the Halo orbit.</p> <p>(Dunham, D., et. al., "SOLAR SYSTEM HUMAN EXPLORATION AIDED BY LIBRATION-POINT ORBITS, LUNAR GRAVITY ASSISTS, AND 'PHASING ORBIT RENDEZVOUS'," 24th International Symposium on Space Flight Dynamics, 2014)</p> <p><b>Impact:</b> A complex Solar System Exploration trajectory is verified using GMAT.</p>
<p><b>Foresight Wireless, University of North Carolina</b></p>	<p>2014</p>	<p><b>Accomplishments:</b> This paper analyzes a specific method of IP-based routing for military satellite ad hoc networks, called Dynamic Autonomous Routing Technology (DART). A simulation, where GMAT is used as the orbit propagator, is performed using the IRIDIUM constellation as an example.</p> <p>(Wang, X., et. al., "Dynamic Autonomous Routing Technology for IP-based Satellite Ad Hoc Networks," Sensors and Systems for Space Applications VII, edited by Khanh D. Pham, Joseph L. Cox, Proc. of SPIE Vol. 9085, 90850P, 2014)</p> <p><b>Impact:</b> With help from GMAT, a DART LEO/MEO Satellite Ad Hoc Network Simulator that can be used to analyze routing performance is built.</p>
<p><b>Technical University of Madrid, University of Colorado</b></p>	<p>2014</p>	<p><b>Accomplishments:</b> GMAT was one of the tools used to help study a concept for extending the capture period of a sample "temporarily captured asteroid."</p> <p>(Urrutxua, H., et. al., "WHAT DOES IT TAKE TO CAPTURE AN ASTEROID? A CASE STUDY ON CAPTURING ASTEROID 2006 RH120," AAS 14-276, 24th AAS/AIAA Space Flight Mechanics Meeting January 26 – 30, 2014, Santa Fe, NM)</p> <p><b>Impact:</b> This research helps further the goals of NASA's Asteroid Retrieval Initiative.</p>
<p><b>Scientific Systems Company, University of Illinois, AFRL</b></p>	<p>2014</p>	<p><b>Accomplishments:</b> An intercept maneuver algorithm is simulated using GMAT. The algorithm developed used Liapunov methods to solve the Low Earth Orbit (LEO) intercept maneuver problem in terms of game-theoretic capture-evasion guaranteed strategies.</p> <p>(Zatezalo, A., et. al., "Constrained orbital intercept-evasion," Sensors and Systems for Space Applications VII, edited by Khanh D. Pham, Joseph L. Cox, Proc. of SPIE Vol. 9085, 90850E)</p> <p><b>Impact:</b> GMAT used as part of a simulation platform to analyze an intercept maneuver algorithm.</p>

<b>West Virginia University</b>	2014	<p><b>Accomplishments:</b> GMAT was the primary tool used to both design and optimize a complicated triple flyby capture at Jupiter. In their paper (Didion, A., Lynam, A., "Impulsive Trajectories from Earth to Callisto-Io-Ganymede Triple Flyby Capture at Jupiter," AIAA 2014-4106, AIAA/AAS Astrodynamics Specialist Conference, 4-7 August 2014, San Diego, CA.), the authors describe the methodology and why GMAT was chosen:</p> <p>In order to generate high-fidelity orbit simulations and formulate optimal conditions for a triple-satellite-aided capture maneuver, the NASA General Mission Analysis Tool (hereafter referred to as GMAT) software is used. The GMAT software was chosen due to its adaptability to such esoteric mission profiles such as that described in this paper as well as its open source availability and computational flexibility and accuracy. While less widely used than other similar astrodynamical propagation software, it is easily reconfigured to fit mission specifics (such as addition of the Galilean moons), provides a simple GUI and script editing interface, and is capable of interfacing with MATLAB in order to use its optimization subroutines.</p> <p><b>Impact:</b> GMAT used to design a complicated interplanetary trajectory.</p>
<b>Millennium Space Systems, Inc.,</b>  <b>AFRL,</b>  <b>Raytheon/Photon Research Associates,</b>  <b>Schafer Corporation,</b>  <b>CENTRA Technology,</b>  <b>DARPA</b>	2014	<p><b>Accomplishments:</b> An architecture to add ground based optical data to other data sources to improve Space Situational Awareness is developed. GMAT is used for orbit propagation of both the target satellites and the sensor platform as part of a simulation using this architecture.</p> <p>(Koblick, D., et. al., GROUND OPTICAL SIGNAL PROCESSING ARCHITECTURE FOR CONTRIBUTING SPACE-BASED SSA SENSOR DATA," <a href="http://www.amostech.com/TechnicalPapers/2014/Sensor_Processing/KOBLICK.pdf">http://www.amostech.com/TechnicalPapers/2014/Sensor_Processing/KOBLICK.pdf</a>)</p> <p><b>Impact:</b> GMAT is used to help verify a GROUND OPTICAL SIGNAL PROCESSING ARCHITECTURE (GOSPA).</p>
<b>Texas A&amp;M University</b>	2014	<p><b>Accomplishments:</b> GMAT was used to verify a simplified procedure for propagating satellite relative motion for low-eccentricity orbits using Kaula's linear perturbation theory.</p> <p>(Yan, H., et. al., "A Simplified Formulation of the Satellite Perturbed Relative Motion Problem," AIAA 2014-4133, AIAA/AAS Astrodynamics Specialist Conference, 4-7 August 2014, San Diego, CA.)</p> <p><b>Impact:</b> GMAT is used to verify some analytical results.</p>
<b>GMV AD,</b>  <b>EUMETSAT</b>	2010	<p><b>Accomplishments:</b> GMV built a Mission Analysis development framework for EUMETSAT. GMAT is used as the orbit propagation engine</p> <p>(Jiménez, F., et. al., "MULTI PURPOSE MISSION ANALYSIS DEVELOPMENT FRAMEWORK MUPUMA," retrieved from website, <a href="http://www.gmv.com/export/sites/gmv/DocumentosPDF/focusSuite/Mission_Analysis_MUPUMA.pdf">http://www.gmv.com/export/sites/gmv/DocumentosPDF/focusSuite/Mission_Analysis_MUPUMA.pdf</a>)</p> <p><b>Impact:</b> GMAT is used as a major component of a new mission design tool.</p>