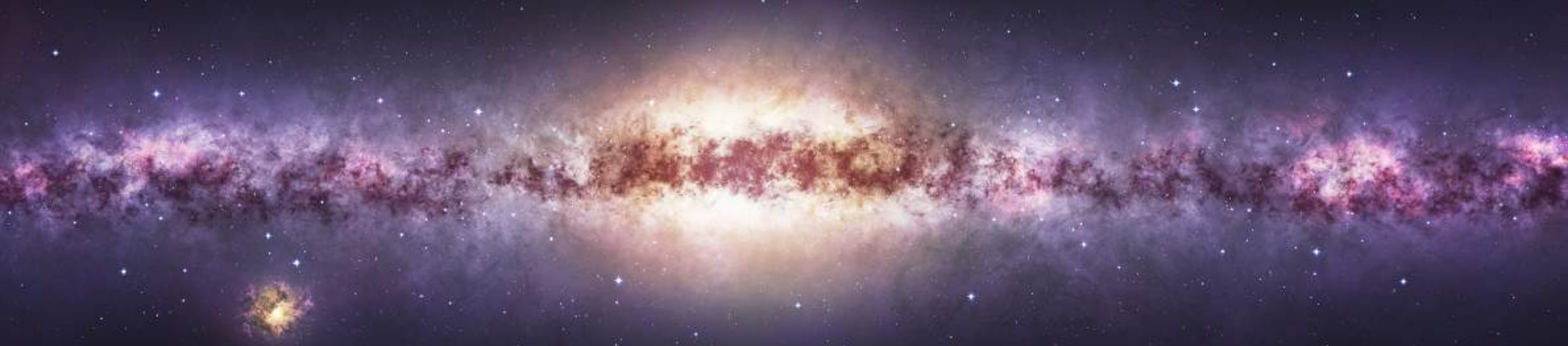
Workshop and Awards Ceremony

of the 11th Global Trajectory Optimisation Competition



CONFERENCE HANDBOOK

Organized by
National University of Defense Technology and Xi'an Satellite Control Center

Changsha, China, December 18, 2021

■ 1.TIPS

1.1 Workshop Time

18 December, 13:00-17:40 UTC

1.2 On-line Entrance

This workshop will take place in a hybrid form including both on-line and on-site participants. For convenience, some Chinese participants are invited to the site, and other participants can join the workshop through online live broadcast.

The broadcast link is

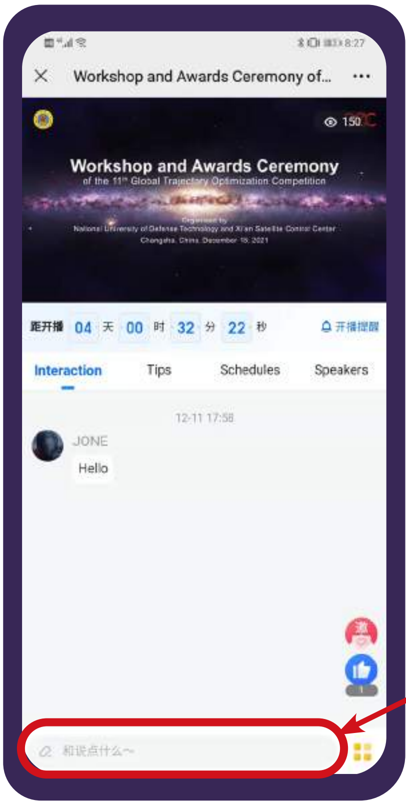
https://wx.vzan.com/live/tvchat-1401167678?v=1639303158274

- Participants outside of China can enter the above link through mobile phone or PC to watch the live broadcast.
- Chinese participants can watch the live broadcast by either entering the above link or scanning the following QR code through WeChat.

You can also enter the above link to watch the video replay if you can't watch the live broadcast on time.

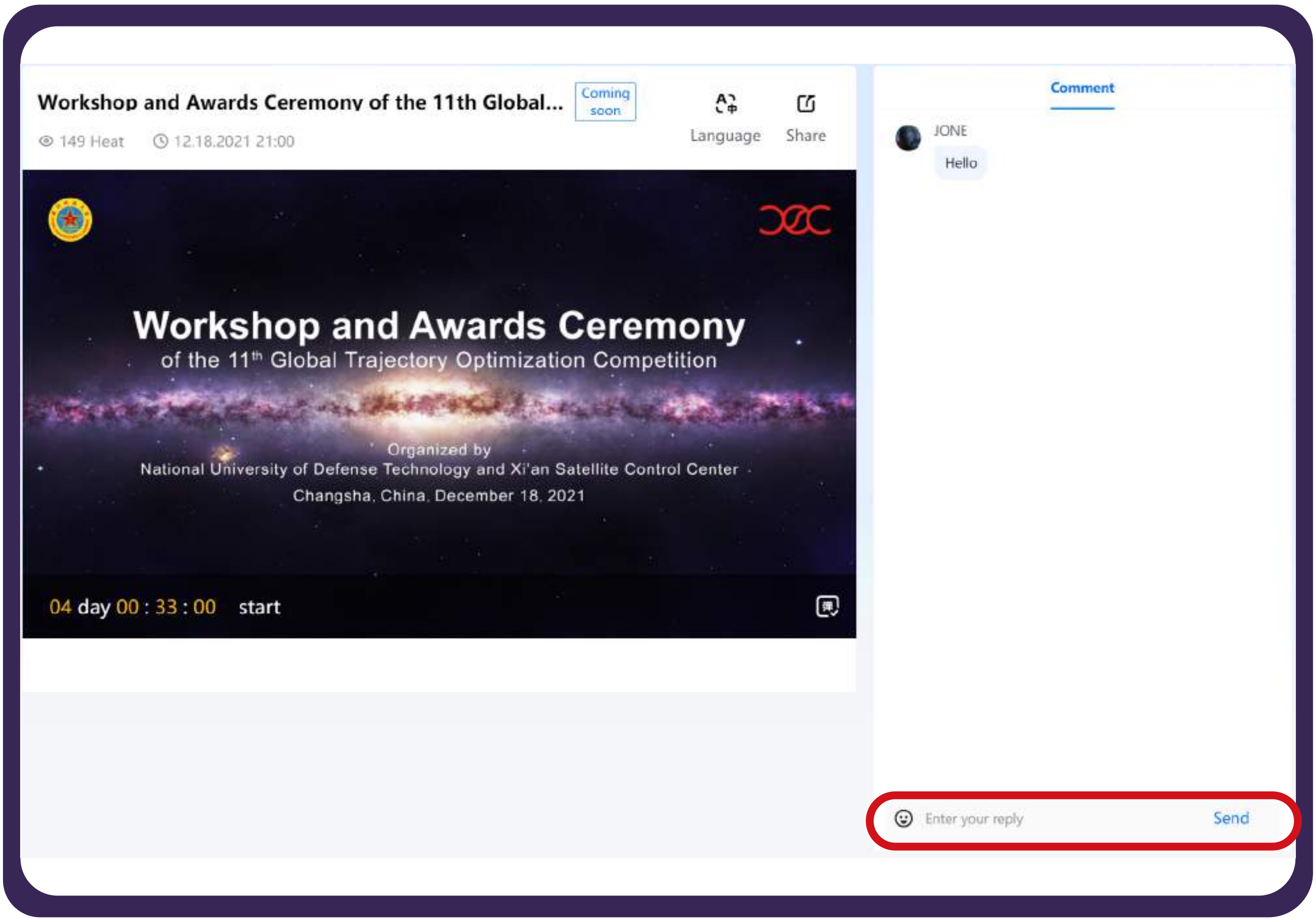
1.3 Interaction

You can ask questions by sending messages on the live broadcast web page. Participants outside of China can log in through Facebook to send messages and Chinese participants can log in through WeChat to send messages. Hosts will broad your question to the speakers. Due to the limit of time, only some good questions will be selected to broad to the speakers. You can contact with the speaker after the workshop if you have more questions.



You can ask questions by sending messages on the live broadcast web page.

Live broadcast page on mobile phone



Live broadcast page on PC

■ 2.SCHEDULES

Session	Time (UTC)	Content
Plenary Lecture	**Host:Prof. Ya-zhong Luo**	
	13:00 - 13:10	Opening Speech & GTOC 11 Awarding (Prof. Jianjun Wu, Vice-President, National University of Defense Technology)
	13:10 - 13:40	The GTOC Series, a Brief History of an Unexpected Journey (Dr. Dario Izzo, European Space Agency)
	13:40 -14:10	Analytic Scaffolding that Simplifies Global Trajectory Optimisation (Dr. Anastassios E. Petropoulos, Jet Propulsion Laboratory)
	14:10 - 14:40	Trajectory Optimization in China (Prof. Baoyin, Tsinghua University)
	14:40 - 14:50	GTOC 11 Summary (Prof. Ya-Zhong Luo, National University of Defense Technology & Dr. Hong-Xin Shen, Xi'an Satellite Control Center)
Break	14:50 - 15:00	
Presentation of the top 10 teams（15:00-17:00）	**Host:Dr. Yue-he Zhu**	
	10 minutes for each team	Beijing Institute of Technology Joint Team
		Nanjing University of Aeronautics and Astronautics Team
		Chinese Academy of Sciences Team
		Harbin Institute of Technology Team
		Thales Services Numériques Joint Team
		The University of Alabama Team
	Host:Dr. Hong-Xin Shen	
	15 minutes for each team	The University of Texas at Austin Team
		The University of Auckland Joint Team
		ESA Advanced Concepts Joint Team
		Tsinghua University Joint Team
Open Discussion	**Host:Dr. Dario Izzo**	
	17:00 - 17:30	The Future of the Competition
Closing Ceremony	**Host:Prof. Ya-zhong Luo**	
	17:30 - 17:40	Closing Speech

■ 3.CONFERENCE ORGANIZER

Chair

Prof. Jian-Jun Wu

Affiliation: National University of Defense Technology, China

Biography: He is currently the vice-president of National University of Defense Technology. He is a member of the China Aerospace Society's Liquid Propulsion Technology Professional Committee, a member of the Chinese Society of Aeronautical Engineers' Rocket Engine Propulsion Committee, and a member of the International Electro-Propulsion Technology Committee. He is mainly engaged in advanced non-chemical space propulsion technology, spacecraft and propulsion system health monitoring technology, rocket engine system dynamics and control technology. His scientific research achievements have been applied in kinds of micro-nano satellites and CubeSats to realize the first space engineering application of pulsed plasma thruster in China, and provided practical and effective technical support for low-cost deorbit and high-precision attitude-orbit control of micro-nano satellites.

Co-Chair

Prof. Ya-Zhong Luo

Affiliation: College of Aerospace Science and Engineering, National University of Defense Technology, China

Biography: He received the BS degree, MS degree and PhD degree in aerospace engineering from National University of Defense Technology in 2001, 2003, and 2007, respectively. He is currently the director of the Applied Mechanics Department in the College of Aerospace Science and Engineering, NUDT. He is awarded by National Natural Science Foundation for Distinguished Young Scholars. He is mainly engaged in the research of aerospace dynamics and control, and manned space mission planning. His scientific research achievements have made important contributions to the development of space stations and the technological breakthroughs in the rendezvous and docking of manned space projects in China.

Dr. Hong-Xin Shen

Affiliation: Xi’an Satellite Control Center, China

Biography: Hong-Xin Shen received his Ph.D. degree in aerospace science and technology from National University of Defense Technology, China, in 2014, and conducted study, respectively, in Polytechnic University of Turin from 2012 to 2013 as a visiting student, in Peking University from 2017 to 2019 as a postdoctoral fellow. Currently, he is an associate professor of Xi’an Satellite Control Center. He is the winner of the tenth edition of the Global Trajectory Optimization Competition (GTOCX). His research interests include trajectory optimization and astrodynamics. His current research interests are space situational awareness and mega-constellation.

■ 4.PLENARY LECTURE

The GTOC series, a brief history of an unexpected journey

Dr. Dario Izzo

Advanced Concepts Team, European Space Agency, Netherlands

Abstract: The Global Trajectory Optimization Competition is an event taking place every one or two years over roughly one month during which the best aerospace engineers and mathematicians world wide challenge themselves to solve a “nearly-impossible” problem of interplanetary trajectory design. The problem is released by the winning team of the previous edition who, also, is free to define entirely the competition rules. Since 2005, a total of 11 edition GTOCs have been successfully held. This presentation shows a brief history of the unexpected journey of the GTOC series.

Biography: He received the master degree in aeronautical engineering from the Sapienza University of Rome, Italy, a second master degree in satellite platforms from the University of Cranfield, U.K., and the Ph.D. degree in mathematical modelling from the Sapienza University of Rome, in 1999, 2001, and 2002, respectively. He was a Lecturer in classical mechanics and space flight mechanics under the guidance of Prof. C. Valente with the Sapienza University of Rome. He joined in 2003 the European Space Agency, Noordwijk, The Netherlands, as a researcher and became the Scientific Coordinator of its Advanced Concepts Team which is currently heading. He devised and is managing the Global Trajectory Optimization Competitions events, the ESA Summer of Code in Space, and the Kelvins innovation and competition platform. He was the recipient of the Humies Gold Medal in 2013 for his work on the automatic planning of Jupiter moons tours.

Analytic Scaffolding that Simplifies Global Trajectory Optimisation

Dr. Anastassios E. Petropoulos
Jet Propulsion Laboratory, California Institute of Technology, USA

Abstract: JPL has been involved with all of the first ten GTOCs. Throughout all of them, and in particular when competing, it has always been clear that analytical insights into the trajectory dynamics should be sought and utilised as part of any global optimisation strategy. Here we present many of the insights that were developed and incorporated into the search for the global optimum of each of the GTOC1-GTOCX problems.

Biography: He has been at the Jet Propulsion Laboratory since 2001 when he received his PhD is Aeronautics and Astronautics from Purdue University. He is currently part of the Mission Design team for NASA's Psyche Mission, a low-thrust mission to orbit the asteroid 16 Psyche. He has worked extensively in the field of low-thrust and gravity-assist trajectory design, both for mission proposals and in a research capacity. He has also led the JPL GTOC teams beginning with the inaugural competition in 2005.

Trajectory Optimization in China

Prof. Hexi Baoyin

School of Aerospace Engineering, Tsinghua University, China

Abstract: In the last two decades, the Global Trajectory Optimization Competitions (GTOC) have witnessed the progress in the field of the interplanetary trajectory design, the development of new optimization techniques, and the achievement of different teams. Inspired by the GTOC series, Tsinghua organized the first China Trajectory Optimization Competition (CTOC) in 2009, four years after the first GTOC. So far, both of them have been held for 11 editions and released many interesting problems. This presentation will review the results of Chinese teams in the GTOC series and especially include the experience of Tsinghua as a "long-distance runner." The organization and progress of the CTOC series, which shows different concerns with the GTOC because of the very different participating teams, will be reviewed. Finally, the latest developments in the trajectory optimization techniques related to the GTOC and CTOC will be reported.

Biography: His research interests include astrodynamics and trajectory optimization. He has published hundreds of papers in the top journals including Nature/Astronomy, AIAA journals, and listed as a High Cited author in Elsevier Publisher. His research works were reviewed twice in MIT Technology Review to be highlighted with his outstanding innovative ideas. His team participated in all 11 editions of the Global Trajectory Optimization Competition (GTOC) and Chinese Trajectory Optimization Competition (CTOC). He was also the initiator of the CTOC in 2009.

■ 5.PRESENTATION OF THE TOP 10 TEAMS

Rank 1

GTOC 11: Results from Tsinghua University and Shanghai Institute of Satellite Engineering

Dr. Zhong Zhang

School of Aerospace Engineering, Tsinghua University, China

Abstract: Results from Tsinghua University and Shanghai Institute of Satellite Engineering for the 11th Global Trajectory Optimization Competition (GTOC 11) are presented, and the methods used in the global and local optimization are detailed, respectively. Firstly, the pre-analysis shows that the two-impulse transfers are near-optimal in most flyby situations, the semi-major axis of the Dyson ring should be better at 1.0~1.5 Au, and the corresponding asteroids with better final mass tend to be selected. The globally optimal trajectory design problem is further divided into two sub-problems, the trajectory of motherships design and the "Dyson Ring" power stations assignment of asteroids. For the first problem, we used beam search to obtain numerous single mothership trajectories based on a pre-constructed optimal flyby trajectory library of 3-8 asteroids. Then, the genetic algorithm was implemented to select 10 single mothership trajectories to obtain the overall trajectories and asteroids visited. For the second problem, we made a database of the optimal rendezvous time for all 83453 asteroids to reach power stations of different radii and phase angles, and then we used a greedy-like algorithm to obtain the result. The local optimization of asteroid sequence and flyby epochs is conducted, and the indirect continuous-thrust trajectory optimization is used based on the global optimization result. In the final submission, motherships flew by 388 asteroids, and the minimum mass of twelve power stations reached 94% of the theoretical upper bound.

Speaker’s Biography: He received his bachelor's degree in aerospace engineering from Tsinghua University, Beijing, China, in 2019. He is currently a Ph.D. student in the School of Aerospace Engineering at Tsinghua University. His research interests include intelligent optimization algorithms and trajectory optimization.

Rank 2

The fellowship of the Dyson ring: ACT&Friends results and methods

Dr. Marcus Märtens
Advanced Concepts Team, European Space Agency, Netherlands

Abstract: Dyson spheres are hypothetical megastructures encircling stars in order to harvest most of their energy output. This talk describes the approach the ACT&Friends fellowship proposed to solve the GTOC XI challenge during which participants were tasked with constructing a precursor Dyson structure, a heliocentric ring made of 12 stations. A lazy race tree search and a machine-learned Edelbaum approximator are used to identify asteroid sequences of interest to collect the necessary mass for the ring's construction, to be delivered to the stations. For all selected asteroids, a series of optimally phased low-thrust transfers to all stations are computed using indirect optimization techniques, exploiting the synodic periodicity of the system. These transfer possibilities are used to construct a mass-balanced arrival schedule by means of a modified Hungarian scheduling algorithm coupled with differential evolution optimisation.

Speaker's Biography: He graduated from the University of Paderborn (Germany) with a Masters degree in computer science. He joined the European Space Agency as a Young Graduate Trainee in artificial intelligence where he worked on multi-objective optimization of spacecraft trajectories. He was part of the winning team of the 8th edition of the Global Trajectory Optimization Competition (GTOC) and received a HUMIES gold medal for developing algorithms achieving human competitive results in trajectory design. The Delft University of Technology awarded him a Ph.D. for his thesis on information propagation in complex networks. After his time at the network architectures and services group in Delft (Netherlands), Marcus rejoined the European Space Agency, where he works as a Research Fellow in the Advanced Concepts Team. While his main focus is on applied artificial intelligence and evolutionary optimization, Marcus has worked together with experts from different fields and authored works related to neuroscience, cyber-security and gaming.

Rank 3

The Antipodes solution approach to GTOC 11

Prof. Roberto Armellin
The university of Auckland, New Zealand

Abstract: The approach developed by the Antipodes team to tackle the GTOC 11 challenges is presented. Our solution methodology is split in four main blocks: the mothership chains, the table generation, the dispatch problem, and the refinement. For chains generation we started by pruning the asteroid catalogue with considerations on orbital parameters and asteroids mass. A global optimisation problem was then used to understand optimal ring location and chain length, considering a single transfer time between asteroids. The results informed a beam search optimisation process aimed at finding chains that delivered the maximum mass to the ring while spending minimum Δv. Asteroids-to-asteroids transfers were modelled by Lambert's arcs, whereas the arrival mass at the ring estimated by Edelbaum's solution. For all asteroids in the chains we generated tables containing all the possible transfer opportunities to ring stations within the mission duration. These transfers were computed by solving time optimal orbital transfers (no rendezvous) with an indirect method. For a given station, the rendezvous opportunities were efficiently calculated by interpolation of a set of orbital transfers computed on a single asteroid revolution and by solving a phase matching problem. The tables were then transferred to the dispatch algorithm that optimally allocated asteroids to stations while minimizing the GTOC 11 objective function. The final step involved the rapid transformation of orbit transfers into rendezvous transfers, the removal of unused asteroids from mothership chains, and the addition of deep-space maneuvers for fixed encounter epochs. Our solution approach made limited use of high performance computing, the entire problem can be solved with a few hours' calculation on a standard laptop.

Speaker's Biography: He is a professor at the Te Pūnaha Ātea — Space Institute where he leads the research in astrodynamics, mainly in space situational awareness and mission analysis.

Rank 4

The University of Texas at Austin GTOC 11 Solution Using Lookup Tables, Lambert Calls, Indirect Optimization, and a Genetic Algorithm Scheduler

Dr. Sean McArdle

University of Texas at Austin, USA

Abstract: The UT Austin team presents their methodology and final result for GTOC 11, constructing a hypothetical Dyson ring using asteroids encountered by ten motherships departing from Earth. A pathfinding algorithm for the mothership is designed using a fast lookup table for asteroids, a robust Lambert solver, and a ranking schemed on expected contributions to the performance index. Sequencing of the unique mothership itineraries is performed by approximating the mass delivered to the ring via a linear data-based estimator trained over thousands of simulated asteroid-to-ring trajectories. Necessary conditions for an indirect boundary value solver are derived and the solver is implemented using Message Passing Interface (MPI) parallelization to find feasible asteroid-to-ring trajectories for each of the twelve phasing locations. A genetic algorithm informs the sequencing for the ring station arrival order that gives the highest performance index value. A grid search is performed over the Dyson ring semimajor axis. UT Austin's best solution has a performance index value of 5885.5, with 235 asteroids collected, and a minimum ring station mass of 1.1328e+15 kg.

Speaker's Biography: He is currently a PhD. Candidate from Aerospace Engineering and Engineering Mechanics at the University of Texas at Austin.

Rank 5

A Near-Deterministic Strategy for Constructing the GTOC-11 Dyson Ring

Dr. James Pezent

University of Alabama, USA

Abstract: This work, we describe our solution approach for the 11th Global Trajectory Optimization Competition (GTOC-11). This problem tasked the competing teams with the construction of a futuristic Dyson Ring utilizing materials acquired from the asteroid belt. In total, 10 motherships would depart from Earth in the year 2121 and visit as many asteroids as possible. After visiting each asteroid, a low thrust propulsion module would transfer the material down to the desired final Dyson stations. In our approach, we utilized a deterministic tree search that involved alternating between fixed time of flight Lambert searches and solutions to the full-fidelity optimal control problem. Once a single tour had been constructed, transfer trajectories were computed for each asteroid to as many of the building stations as possible. After computing a pool of many thousands of these completed legs, a bin packing algorithm was used to determine the highest scoring combination of 10 solutions. This search process was implemented in Python using our soon-to-be released trajectory optimization tool, ASSET. Ultimately, our team finished 5th with a score of 5525.38.

Speaker's Biography: He is a third year Ph.D. student at The University of Alabama. He graduated from the University of Alabama in the Spring of 2019 with a bachelor's degree in Aerospace Engineering. He is the recipient of the University of Alabama's Francko Fellowship as well as the NSF Graduate Research Fellowship. He currently works in the Astrodynamics and Space Research Laboratory at UA conducting research on trajectory design, optimization, and solar sails. He has interned at the EV/42 Guidance Navigation and Mission Analysis branch at NASA Marshall Space Flight Center and continues to collaborate with MSFC on the Solar Cruiser mission.

Rank 6

Methods and results of the Eccentric Anomalies to build a Dyson ring

Dr. Romain Serra
Thales Services Numériques, France

Abstract: The presentation succinctly describes the best approach of the team ranked 6th at the Global Trajectory Optimization Competition 11. The overall problem is divided sequentially into two main sub-problems, before the final tweaks to the solution. The first one aims at picking the asteroid flyby sequences, relying on a guess of the final mass depletion based on analytical estimations of the time of flight thus only requiring a rough idea of the ring's orbit, and the second one deals with their dispatch to the stations, working with feasible low-thrust trajectories to a now fixed Dyson sphere (equatorial at 1.3 Astronomical Units) thanks to further analysis with the analytical approximations. The asteroid flyby sequences are computed through a beam search with Multi-Objective ranking, on a set of candidates filtered in for their high expected mass on arrival at the ring. At this stage, the departure from Earth uses analytical maneuvers calculated beforehand and the asteroid-to-asteroid legs are one- or two-impulse transfers to a flyby state respecting the relative velocity constraints. Transfers are detected using nearest-neighbor queries and delta-Vs are estimated with a Lambert arc. The flyby dates are then modified via a Multi-Objective approach before being refined via a Single-Objective one, in particular allowing for more than two impulses optimized from initial guesses obtained with the linearized dynamics. In the second part, the asteroids are now the input to the scheduling problem of the transfers. First, a pool of feasible low-thrust trajectories is generated via both direct and indirect methods to solve an underlying time-minimal optimal control problem. A mixed-integer problem is then solved to optimize the station building time intervals and assign asteroid-station pairs, using a bi-level approach with differential evolution in the upper level and a simple heuristic in the lower level. Finally, adjustments are made to further improve the performance index: local optimization of the asteroid flyby sequence after removal of useless visits, re-optimization of the low-thrust trajectories by shifting departure or switching method, etc. Compared to other top-scoring teams, the final best solution has a relatively high number of asteroids and mass to the ring.

Speaker's Biography: He graduated with various degrees in mathematics and engineering from schools in Toulouse (France) and the University of Michigan (USA). After completing his PhD in control engineering in 2015, he was a research associate for two years at the University of Strathclyde in Glasgow (UK), where he participated for the first time to the GTOC. He has since led teams in every subsequent editions. Although he was an engineer at Thales in Toulouse at the time of GTOC 11, he is now with Share My Space, a French start-up which aims to track 100,000 orbital debris by 2023.

Rank 7

GTOC 11: Results and methods from the HIT team

Dr. Haiyang Zhang

Harbin Institute of Technology, China

Abstract: This presentation introduces the methods proposed by the team of Harbin Institute of Technology in the 11th Global Trajectory Optimization Competition (GTOC 11). The whole task is divided into four parts, including the estimation of the asteroid transfer time, the mother ship trajectory optimization, the Dyson ring construction analysis, and the low thrust trajectory optimization. The best score of our team is 5208, the radius of the selected Dyson ring is 1.1 AU, a total of 250 asteroids are rendezvoused, and the minimum remaining mass is 1.0855e+15 kg.

Speaker's Biography: He received the B.S. and M.S. degrees in aerospace science and technology, in 2017 and 2019, respectively, from the Harbin Institute of Technology, Harbin, China, where he is currently working toward the Ph.D. degree in aerospace science and technology with the Research Center of Satellite Technology. His research interests include orbital ground track adjustment and low thrust trajectory optimization.

Rank 8

Global optimization method based on databases for multi-satellite and multi-target trajectory design

Dr. Shengmao He

Chinese Academy of Sciences, China

Abstract: The global optimization of multi-satellite and multi-target trajectory usually poses a huge optimization space, which greatly challenges the computing ability and efficiency for each participating team. In order to reduce repeating calculation and invalid calculation, we put forward the ‘database method’ (DBM), which can be regarded as exchanging memory space for calculation amount in essence. Firstly, the range of Dyson loop orbit’ semi-major axis is 1AU ~ 1.5 AU through simplified analysis, the semi-major axis is preliminarily selected to be 1.3 AU, and the continual thrust trajectory from each asteroid to Dyson ring is optimizated without considering the phase constraint of rendezvous Dyson ring, according to which the residual asteroid mass and the latest departure time of each asteroid is obtained and 5000 alternative asteroid targets are screened out according to the residual mass. Then, the databases (including the transfer trajectory database between two asteroids and the pointer database of two adjacent transfer trajectories) is established, where, the transfer trajectory between the two asteroids are calculated by Lambert method, the flight time is 10 days to 200 days, and a grid point is taken every 10 days. When the flyby relative velocities of the two asteroids are both less than 2.2 km/s, then the transfer orbit are recorded into the transfer trajectory database. For each two adjacent transfer trajectories, it is necessary to apply a velocity impulse when flying by the conjunctive asteroid. If the impulse is less than 0.5 km/s, it is considered that the two transfer trajectories can be connected, and the connect-pointer data is recorded into the pointer database. According to the transfer trajectory database and the pointer database, the asteroid flyby sequence is then randomly generated by using the 'Monte Carlo method', and the optimal parameters with the maximum performance index are retained. After that, remove the already selected asteroids from the two databases, update the two databases, and repeat the above processes. Finally, we got a solution of 4794 points with 294 asteroids and the minimum mass of Dyson Ring stations was 1.5e9 kg.

Speaker’s Biography: He graduated from Technology and Engineering Center for Space Utilization, Chinese Academy of Sciences. He has participated in the GTOCs since the sixth edition. He always tried to put forward novel solutions to solve the global optimization problems. At present, the highest known scores of GTOC6 and GTOC8 are designed by him. This year, he together with several friends participate in GTOC11 and put forward the ‘database method’. After the GTOC11, they would improve the database method and expect to get a higher score.

Rank 9

11th Global Trajectory Optimisation Competition: Results found at NUAA

Dr. Xuewen Liu

Nanjing University of Aeronautics and Astronautics, China

Abstract: The method used by the team from NUAA for the problem of GTOC 11 is shown in the presentation. The problem is mainly decomposed into three parts: multiple targets flyby sequence optimization for the Mother Ships, continuous-thrust time-optimal trajectory optimization for the asteroids and the dynamic programming for the station building. After analyzing the data of all the asteroids and screening according to the orbital elements and mass of the asteroids, 1045 asteroids are chosen as candidate targets for the Mother Ships. Genetic algorithm, branch and bound method are applied to a two-impulse asteroid flyby problem and determine the rendezvous sequence of each Mother Ship. Subsequently, on purpose of decreasing the velocity increment, an impulse re-optimization algorithm is utilized to further optimize the transfer trajectory. Then, an indirect method for continuous-thrust time-optimal trajectory is utilized to find the optimal phases of both asteroids and stations. The trajectories of the asteroids are discretized on phase to get the phases of corresponding stations. With the obtained optimal phases, an initial database, which includes number of the asteroids, time of activating the ATDs, number of the stations, is constructed. Thereafter, a feasible trajectory database, appending flight time and final mass, is constructed by solving the continuous-thrust rendezvous problem. At last, a dynamic programming algorithm based on greedy principle is adopted to get the result by maximizing the minimum cumulative mass among the stations.

Speaker’s Biography: He is currently working toward a PhD degree with the College of Astronautics, Nanjing University of Aeronautics and Astronautics. He received the bachelor's degree in detection, guidance and control techniques in 2017.

Rank 10

Parallel beam search technique and deep neural networks estimation for multi-impulse transfers

Dr. Shaozhao Lu
Beijing Institute of Technology, China

Abstract: In the design of Dyson ring building mission, a four-level optimization framework is presented to solve the complex optimization problem. Firstly, the free- phase low-thrust optimization problem of candidate asteroids and grid search method are combined to determine for the Dyson ring's semi-major axis and inclination. Secondly, the sequence optimization problem is solved by beam search with a parallel computing technique. Thirdly, the building station sequences are optimized by coordinate descent and particle swarm optimization method. Finally, the local optimization problem of the multi-impulse transfers is addressed by deep neural networks estimation and sequential quadratic programming.

Speaker's Biography: He received his Bachelor Degree of Engineering in Aircraft Design and Engineering from Beijing Institute of Technology, Beijing, China, in 2018. From 2018, he is a Ph.D. Candidate at the School of Aerospace Engineering, Beijing Institute of Technology. His research interests include in-orbit assembly, swarms of spacecraft trajectory optimization, and orbital dynamics and control.

6.AWARD-WINNING TEAM

The Winner

Affiliation: Tsinghua University

Members: Zhong Zhang, Nan Zhang, Xiang Guo, Di Wu, Xuan Xie, Jinyuan Li, Jia Yang, Shiyu Chen, Fanghua Jiang, Hexi Baoyin

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Affiliation: Shanghai Institute of Satellite Engineering

Members: Haiyang Li, Huixin Zheng, Xiaowen Duan

The Second Prize

Affiliation: ESA Advanced Concepts Team and Friends

Members: Dario Izzo, Marcus Märtens, Anne Mergy, Emmanuel Blazquez, Moritz van Looz, Pablo Gomez, Giacomo Acciarini; Chit Hong Yam, Javier Hernando Ayuso, Yuri Shimane

The Third Prize

Affiliation: University of Auckland

Members: Roberto Armellin, Laura Pirovano, Minduli Wijayatunga, Adam Evans

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Affiliation: ISAE-SUPAERO

Members: Alberto Fossa, Andrea Bellome, Thomas Caleb, Joan-Pau Sanchez Cuartielles

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Affiliation: University of Surrey

Members: Xiaoyu Fu, Danny Owen, Laurent Beauregard

Affiliation: University of Southampton

Members: Alex Wittig, Cristina Parigini