The Norman and Helen
Asher Space Research Institute

המכון לחקר החלל
ע"ש נורמן והלן אשר

Assoc. Prof. Pini Gurfil - Director
פרופ"ח פיני גורפיל - מנהל

Report

on the

Space **A**utonomous **M**ission for **S**warming

and

Ge**o**-Locating **N**anosatellites
SAMSON

supported by

Fondation Adelis

March 2017

SAMSON in a Nutshell

As previously reported, SAMSON is the Technion's **S**pace **A**utonomous **M**ission for **S**warming and Ge**o**-locating **N**anosatellites. SAMSON aspires to be the world's first university-built 3-nanosatellite autonomous cluster flight mission with a projected commercial launch to low Earth orbit in 2017. The satellites are designed, assembled and operated mostly by the SAMSON team of researchers and engineers from ASRI, Aerospace Engineering students and the collaborating Israeli industries.

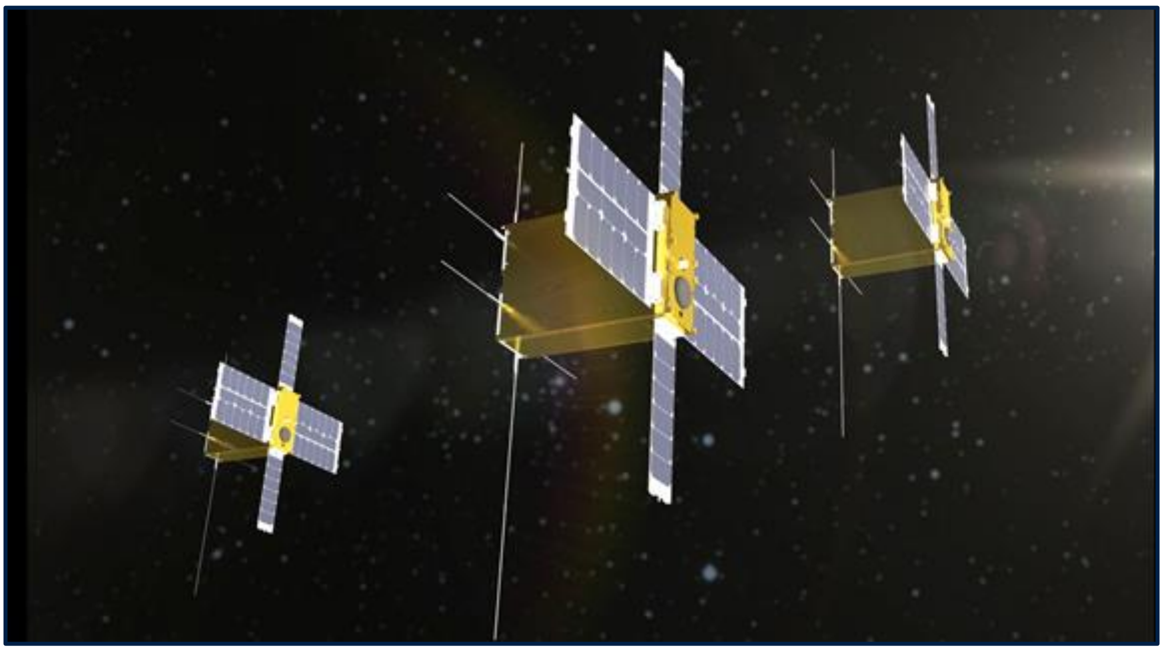


Figure 1: Artists's Concept of SAMSON

The three SAMSON satellites will fly in a cluster, where the distance between any two satellites is not less than 1 km and not more than 250 km, for a full year. The cluster will be further employed to locate cooperative terrestrial signals at high precision for applications such as search and rescue in the ocean or in disaster zones. For this we will build a dedicated ground emitter to be located on the Technion campus. The geo-location will be based on Time Difference of Arrival (TDOA) and Frequency Difference of Arrival (FDOA) methods. SAMSON uses a new space processor initially designed at the Technion's Faculty of Electrical Engineering. For this ambitious mission, we have developed (with Rafael Ltd) a new cold-gas propulsion system and a dedicated geo-location payload (with IAI/Elta).

Project Status

The SAMSON project officially started in March 2012 with a Systems Requirement Review (SRR) in which the mission's Systems Requirements document was presented and discussed. The event was very well attended by Technion personnel, as well as by engineers from the leading space industries in Israel, and a few interested parties from abroad. Since the SRR, we have slowly but surely assembled a large and diverse team to work on the mission. At least one general team meeting is held every week and additional smaller meetings as needed. The team has developed a detailed mission concept and the design of the SAMSON satellites. At present, we are in the process of developing the ground station and defining the test procedures for flight readiness.

The following milestones were successfully achieved:

- March 2012 — Systems Requirement Review
- July 2013 — Preliminary Design Review
- July 2014 — Critical Design Review
- February 2015 — Integration Readiness and Kick-Off Review
- December 2015 — Propulsion Pressure Tank Manufactured
- January 2016 — Payload Development Completed
- May 2016 — Ground station development started
- July 2016 — Testing of accurate timing system complete
- December 2016 — Ground station development & procurement complete

The project is on track for the planned launch in the fourth quarter of 2017.

The Team

Our team now consists of Technion professors and administrators, ASRI researchers and engineers, former and present Technion students, and space engineers from the industry (many of whom are Technion graduates). There are currently about 50 members of the SAMSON team.

Project Management and Steering Committee

Assoc. Professor Pini Gurfil is the project director. In addition, some of the most experienced experts of Israel's space program have been recruited as members of the Steering Committee to the project:

Professor Moshe Guelman (Technion) – former director of ASRI and a prominent space scientist;

Dr. Daniel Choukroun (Ben-Gurion University of the Negev) – leader of the satellite development program in BGU, and an experienced space scientist;

Shmaryahu Aviad (Israel Space Agency) – former senior manager in the Israeli space program;

Moshe Shachar (Ministry of Defense) – senior expert on satellite systems and the past manager of the TECHSAT satellite program at Technion.

In addition, the project team regularly consults with experts from the Israel Aerospace Industries (IAI) space division, former founders and leaders of Israel's military space program, Israeli Space Agency (ISA) officials, professors, and space engineers. These advisors are invited to some of the meetings and design reviews, and provide feedback, which is taken into consideration and implemented as needed.

Two professionals are employed to lead SAMSON to a successful launch: Avner Kaidar as SAMSON's primary systems engineer, with a few decades of experience in Rafael and other industries, and a former leader of several large communications projects; and Shlomo Balaban, an experienced mechanical engineer as the coordinator of this complicated consortium.

Furthermore , IAI allocated their own project manager, Mr. Ephie Sagie, in addition to numerous professionals in the fields of electrical engineering, who developed the satellite basic units and systems (BUS), thermal analysis, integration experts (that built all of Israel's satellites), satellite testing specialists, as well as a launch manager. Rafael is contributing Jacob Herscovitz, who is responsible for personally instructing the annual student projects.

Funding

In addition to the support of the Adelis Foundation the project is now also partially supported by Israel's Ministry of Science and Technology (MoST) through grants from ISA (Israel Securities Authority), in addition to the direct Technion funding made possible with the further generous support of another donor.

Undoubtedly, the Ministry of Science and Technology and ISA appreciated the Technion's investment in this prestigious space project and had a strong desire to participate and further endorse it by providing much needed complementary funding. To date, we received two generous grants from ISA. One grant for NIS 2.8 million is dedicated to supporting the study of formation flying and the high launch costs. The second grant for NIS 1 million is to establish a knowledge center for small satellites at ASRI, which is also used to support the SAMSON effort. These ISA grants also allow us to allocate small amounts of funding (NIS 0.6 million) for the work of our partners in the industry.

Recent Activities

In the past year, important progress has been made in all aspects of the design and testing. These include the propulsion system development, ground station site selection, ground station development, and software implementation and testing.

Propulsion System Testing

The propulsion system was designed by RAFAEL in collaboration with engineers from ASRI, according to specifications provided by the project management. In the past year, the titanium-made gas tank was produced. In addition, all remaining components, including valves, wires, and hoses were procured.

Recently, the manufacturing of the pressure tank for the propulsion system has been completed. The SAMSON team has recently completed testing the pressure resilience of the tank through a series of explosion experiments conducted in RAFAEL (Fig. 2). The experiments have shown that the tank can withstand a max pressure of about 600 atmospheres.

Figure 2: Exploded gas tank of the SAMSON Propulsion System

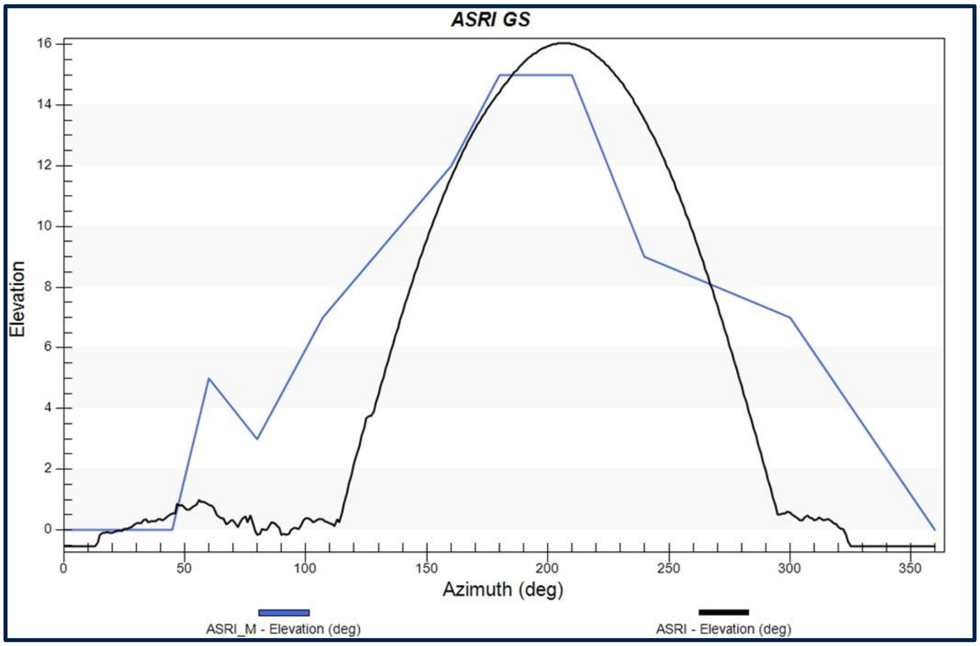
Ground Station Site Selection Considerations

To erect the new ground station for the SAMSON satellites, we had to select an appropriate site on campus. In particular, two sites were considered: one in ASRI, and the other in the Faculty of Electrical Engineering (EE). To compare between the ASRI and EE locations we used a setup which included an alidade and a phone with built in GPS and IMU. Both devices use the same tripod so they are approximately aligned.

Using the above data we created an azimuth-elevation mask which was later embedded into specialized software, called STK.

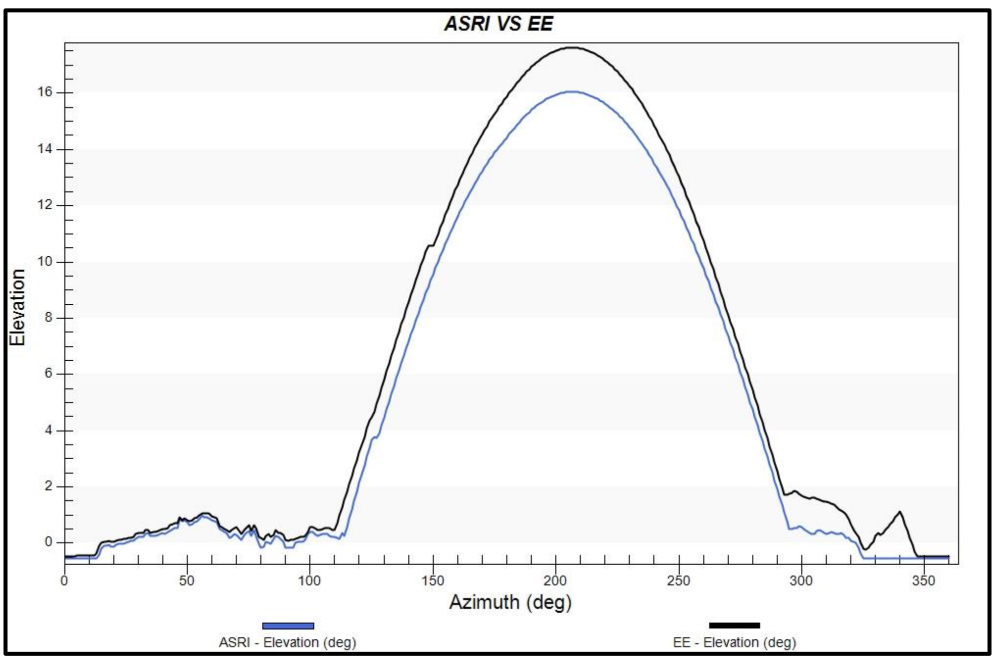
In addition, we calculated the azimuth-elevation mask of the above position using the AGI World Terrain, which offers a terrain of the Earth in 1km resolution.

The following diagram shows a comparison between both methods where the ASRI_M is the manual measurement.



From this we see a good correlation between both methods. Thus, we can use STK to calculate the mask for the EE Ground Station (GS) as well.

The following diagram shows a comparison between ASRI and EE azimuth-elevation mask, as obtained from the STK software.

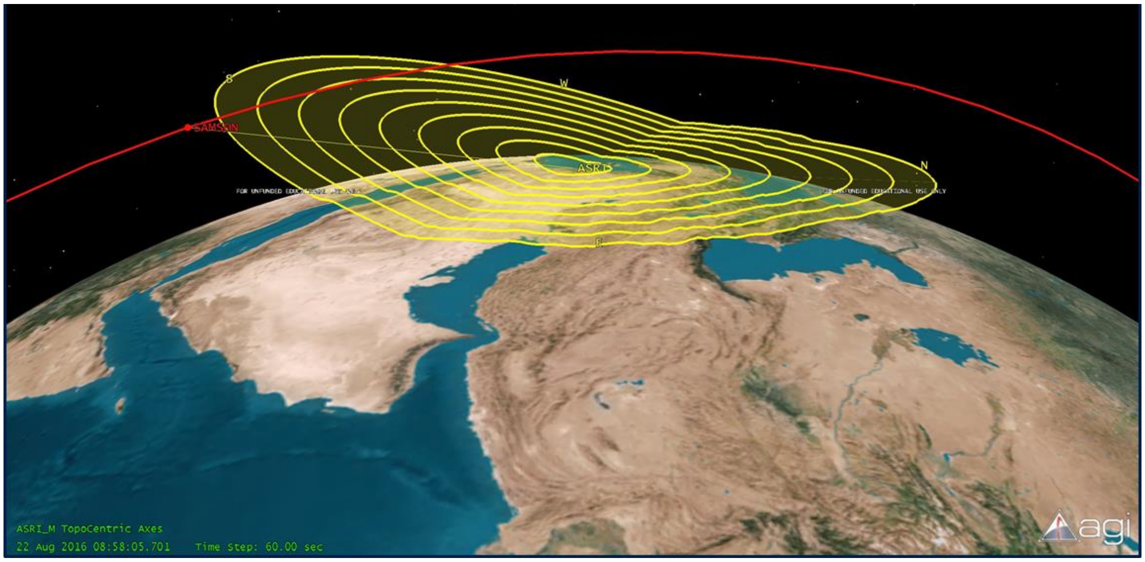


From this analysis, we see that the ASRI location is slightly better than the EE location.

We tested the ASRI GS access duration over a year with a typical satellite orbit, and on top of the azimuth-elevation mask we added a 10 deg elevation limit.

The result shows that when a SAMSON satellite passes over the ground station, the maximum access duration is 572 s, the mean duration is 432 s and the minimum duration is 24 s. In a year we have 1287 valid access slots, meaning 3.5 access intervals per day.

In the following diagram, the yellow lines represent the azimuth-elevation mask



Ground Station Development

We recently finished the design and procurement process of the SAMSON ground station, which is manufactured by the Israeli company ORBIT. The Ground Station antenna system (Fig. 3) is intended to track the SAMSON triple-nanosatellite cluster (6U cubesats). The cluster trajectory will be a Low Earth Orbit (LEO) of about 700km altitude with 1km to 250km variable separation (angle separation up to 20 deg as seen from the GS).

Figure 3: SAMSON Ground Station

The antenna system will be used for telemetry and data downlink as well as for command uplink. The downlink telemetry and payload data will be transmitted on 3 separate channels. The carrier frequencies will be at S-band either in the 2.2-2.3 GHz or 2.4-2.483 GHz frequency ranges. Data rate from each cubesat will be about 2Mbps.

There will be three secondary (backup) UHF downlink channels (one per satellite at different frequencies) and one VHF command and control uplink.

The system will essentially consist of one RX S-band prime focus fed parabolic reflector antenna, two steerable RX UHF quad-Yagi array antenna sub-systems and one steerable TX VHF dual-Yagi array antenna sub-system.

The system consists of the following main components:

1. Model Gaia-100-3.7 antenna system (x 1) made by ORBIT including:

   S-band RX antenna;
   Antenna steering pedestal;
   Antenna Control Unit (ACU);
   Radome enclosure

2. UHF RX antenna system (x 2) including:

   UHF Yagi array: model CY-450Q made by Antenna Experts;
   LNA assembly;
   EL-over-AZ rotator: model RAS/HR made by Spid;
   Rotator driver/controller: model MD-01 made by Spid;
   Power supply: model PS-01 made by Spid;
   Fixed mast

3. VHF TX antenna system (x 1) including:

   UHF Yagi array: model CY-150D made by Antenna Experts
   LNA assembly
   EL-over-AZ rotator: model RAS/HR made by Spid
   Rotator driver/controller: model MD-01 made by Spid
   Power supply: model PS-01 made by Spid
   Fixed mast
   SSPA (optional)

4. Master tracking controller (CFE computer – optionally, supplied by ORBIT) with dedicated software (designed by ORBIT)

5. Ethernet switch (CFE, optionally supplied by ORBIT)

6. System Cabling

The master tracking antenna (Gaia-100-3.7) will track the satellites based on a schedule communicated to it by the GS via Ethernet link. Accordingly, it will employ one of several possible tracking schemes including programmed track, step track and a combination of both. The UHF/VHF antennas will be independently steered to point in the same direction.

All antenna systems and the master tracking controller will be interconnected for monitoring and control via a CFE Ethernet switch (optionally, to be supplied by ORBIT). The master-tracking controller will be a standalone computer which will run a special software utility (designed by ORBIT) that will coordinate the motion of all antennas.

Satellite Dispenser

The current configuration of the SAMSON satellite dispenser will allow for a simultaneous injection of two nanosatellites into orbit (see Fig. 4). The third satellite will be injected from a second dispenser. In the next few months, we plan to conduct a series of experiments for examining the functionality of this dispenser. A series of fit checks will be made to ensure a smooth injection into orbit.

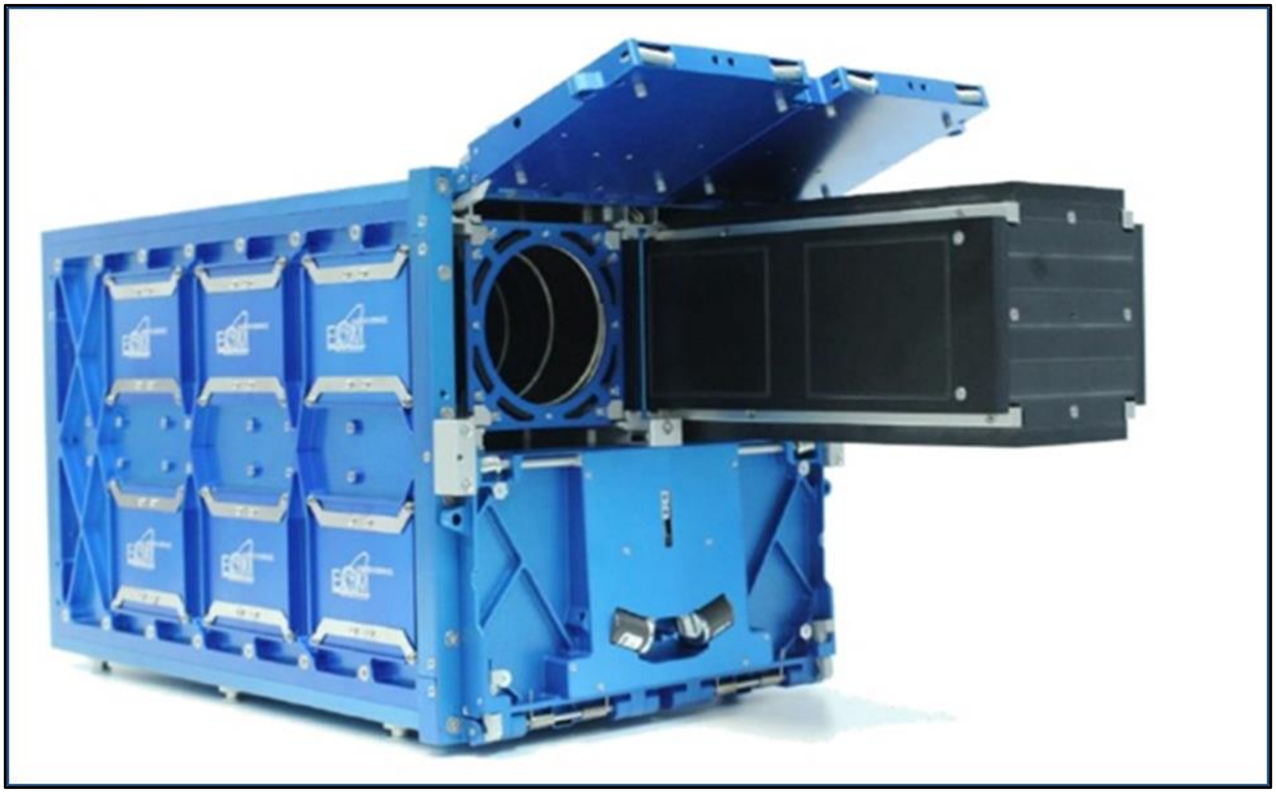


Figure 4: SAMSON Dispenser

Structural and Mechanical Components

We have completed the mechanical design of the SAMSON satellites. It was a complex undertaking of fitting the various components that are totally different from each other into a small nano-satellite, coping with volume and weight constraints, and the requirement to operate in space environment as well as to withstand the mechanical vibrations of the launch. The actual assembled satellite, is shown in Figure 5.

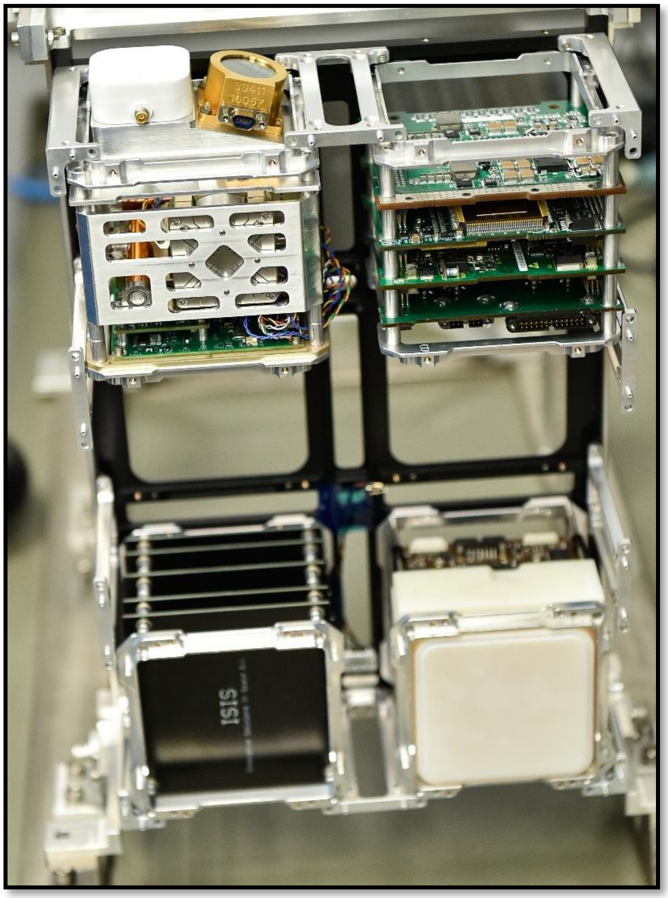


Figure 5: SAMSON Assembly

Cooperation with Industry

The State of Israel is a proud member of the Space Club of Nations, less than ten countries around the globe that design, build, and launch their own satellites. As such, Israel's space industries are world-renowned and have achieved their well-respected standing for the satellites they built and are building and selling today. In contrast, the research at ASRI is focused on the more remote future and on technologies that are not yet implemented in the industry.

Small, university scale satellites, such as those of SAMSON, are turning (on a worldwide basis) into the primary tool for training engineering students as well as for testing novel application in space before they can be implemented on large, commercial satellites. University space research by nature is too far ahead in the realm of the future for the industries to immediately turn concepts and designs into current business plans. Nevertheless, many industries do have the vision and do realize that today's research is tomorrow's potential business.

Over the course of the past two years, the Technion has claimed the role of spearheading small-satellite research in Israel, mostly owing to the SAMSON project. Under the leadership of ASRI, we have now built a diverse group of several dozens of researchers and engineers from the Technion and from the collaborating Israeli industries. In fact, with the onset of the SAMSON project, we were overwhelmed by how the space industries (who can be fierce competitors in other arenas) rushed to join SAMSON under the academic umbrella of ASRI, and are now closely joining forces over SAMSON. The industries are not paid to work with us, but they obviously recognize the technological value of being part of a cutting edge space mission. In the space business, where customers are few, missions are scarce, and heritage (track record) is everything, SAMSON provides a rare opportunity for the industries to be part of a novel, yet real, mission through which their hardware gains precious heritage in space. To that end, one cannot overestimate the status, which real space projects such as Techsat and SAMSON bring to the Technion.

Our Partners in the Industry

The space division of IAI, MBT Space, is Israel's primary space contractor, and the home of Israel's highly successful Ofeq, Eros, and Amos satellite lines. Once SAMSON was conceived, MBT Space generously volunteered to provide systems engineering services to the project as well as their other expertise in attitude and thermal control, thermo acoustic testing, systems integration, and more of its other expertise in satellite building. MBT Space has already spent thousands of engineer work hours for the sake of SAMSON and will surely use many more. MBT Space just now developed a new "bus" (basic units and systems) for nano-satellites. We are in the process of purchasing three such units for the SAMSON satellites, which will be one of the first test beds for the new bus. It is easy to see that our lively collaboration on a university mission has appreciably increased the interest and investment of the IAI/MBT in small satellites.

Rafael Ltd is arguably the single most important backbone of Israel's defense industries and likely its most profitable member. Rafael designs and builds thrusters and thruster components for most of Israel's satellites, and furthermore sells some of these abroad. Rafael was part of SAMSON early on, when one of its engineers was instructing group student projects at the Faculty of Aerospace Engineering. Since SAMSON was conceived two years ago, these projects were geared towards the SAMSON mission. Under the instruction of engineers from Rafael's Space Directorate, Technion students designed the thruster system of SAMSON that will be key to the success of its formation flying and the geo-location missions. Rafael is also providing an experienced mechanical engineer, Michael Zaberchik, who is overseeing the development and complex procurement and manufacturing process of the thrusters in Rafael.

ELTA Systems Ltd., a Group of IAI, is one of Israel's leading defense electronics companies. Along with Elbit Systems Ltd, it was passionate to build the geo-location payload for SAMSON. We eventually ended up teaming with Elta, although no doubt Elbit could have been a highly competent partner as well.

Several Elta engineers are core members of the SAMSON team and working closely with the SAMSON team to develop the geo-location payload. Elta has never before built such an instrument for space, so they are obviously interested in exploiting this opportunity to potentially develop new expertise they would not have had without SAMSON.

Launch

The Launch is arguably the single most important and expensive aspect of the SAMSON mission. Given that we need to buy a commercial launch, we have been meticulously studying the market and vigorously exploring all of the launch opportunities out there. Currently, we have launch offers from several launch providers in several different countries ranging in price from $1.1 million to $1.5 million. Some of these offers also include the engineering launch campaign services that guarantee that our satellites are compatible with the launcher, and that they meet its engineering requirements. We are also exploring international collaborations that may provide an opportunity for cheaper launches. We are in the midst of negotiations with all of the providers. These are complex negotiations that involve lawyers, export control guidelines, and occasionally international diplomacy.

Although the finalization of the launch agreement is delayed, ASRI is looking to sign the contract as soon as possible, in order to be ready for the launch in 2017.

SAMSON - Stage 2

FINANCIAL STATEMENT

October 2015 – September 2016

	2015/16
INCOME	$
Grant Received	624,987
EXPENDITURE	
Salaries – Faculty and Technical Staff	162,720
Graduate Fellowships	87,174
Total Expenditure	249,894
BALANCE OF FUNDS for future work	**375,093**
BALANCE brought forward from	**375,207**
TOTAL BALANCE OF FUNDS	**$750,300**

The Technion
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