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54th IAA HISTORY OF ASTRONAUTICS SYMPOSIUM (E4) History of Middle Eastern Contribution to Astronautics and Astronomy (3) Author: Mr. Tal Inbar former head of space center at the Fisher Institute for Air and Space Strategic Studies, Israel, [talinbar@fisherinstitute.org.il](mailto:talinbar@fisherinstitute.org.il)

**TAUVEX - THE ODYSSEY OF AN ISRAELI SPACE TELESCOPE**

Abstract

The Tel Aviv University Ultraviolet Explorer, or TAUVEX was space telescope array conceived by Noah Brosch of Tel Aviv University and designed and constructed in Israel for Tel Aviv University by El-Op Electro-Optical Industries, Ltd., a division of Elbit systems. It was back in 1988 that the Israel space agency approach the academia for proposals of space related telescopes. acting as Prime Contractor, for the exploration of the ultraviolet (UV) sky. Although originally slated to fly on a national Israeli satellite of the Ofeq series, TAUVEX was shifted in 1991 to fly as part of a Spektr-RG international observatory, a collaboration of many countries with the Soviet Union (Space Research Institute) leading. Due to repeated delays of the Spektr project, caused by the economic situation in the post-Soviet Russia, ISA decided to shift TAUVEX to a different satellite. In early-2004 ISA signed an agreement with the Indian Space Research Organization (ISRO) to launch TAUVEX on board the Indian technology demonstrator satellite GSAT-4. Prior to launch it was removed from the launcher by India, and later returned to Israel – finally cancelled in 2012. The paper will describe thoroughly the history of the space telescope, spanning over 24 years – starting in 1988. It was a technological feat – but its fate was to stay on the ground.

**Introduction**

Israel Space Agency (ISA) was formally established in 1983 and was operated under the Ministry of Science and Technology. As early as 1988, alongside with the launch of Israel's first technological satellite Ofek-1 (Hebrew for "Horizon"), Israel Space Agency issued a call for proposals of scientific payloads of which one will be included in a dedicated scientific satellite, based upon the Ofek satellite platform. It is remarkably interesting to see the scientific application of a military reconnaissance satellite at the verry beginning of the Ofek program. The Israel Space Agency received many suggestions, of which 2 were the finalists: An X-Ray space telescope that was suggested by the Technion, and a UV telescope, suggested by the Tel Aviv University. An international advisory panel helped the Israel space agency and the decision was made to choose the wide-field telescopes to image astronomical objects in the ultraviolet (UV), was selected with the highest priority. This payload is referred to as **TAUVEX**, the **T**el **A**viv **U**niversity **UV** **Ex**periment. Observations in the UV region longward of Lyman alpha, up to the atmospheric transmission limit of ~ 3000A°, take advantage of the reduced sky background. In this spectral region it is possible to observe faint astronomical sources with a high signal-to-noise ratio even with a modest telescope.

The leading scientific team of Tel Aviv University consisted of Prof. Hagai Netzer, Dr. Noah Brosch (the principal investigator during the project long life) and others – all from the school of astronomy and the Wise observatory of Tel Aviv University.

תמונה שמכילה שולחן

התיאור נוצר באופן אוטומטי

Figure 1 – ***Rendering of the dedicated scientific satellite with TAUVEX inside***[[1]](#footnote-1)

The budget for the project was about 20 million USD – considered very large for Israeli civilian space project at the time.[[2]](#footnote-2) Israel space agency choose ELOP as the contractor to build the telescope.[[3]](#footnote-3) After considerable engineering work already done by ELOP, it was decided by ISA NOT to build a dedicated scientific satellite – and to build the telescope as an ad-on payload to be incorporated with a satellite of other country. The main reason for the decision was budgetary constraints, but it could be assumed that the ministry of defense, which was responsible for the OFEQ program, was reluctant to give priority for a civilian project over its own reconnaissance satellites program. After the decision to fund just the telescope and not a whole satellite, ISA begun to search for a possible candidate on which the TAUVEX payload could be mounted on.

תמונה שמכילה שרשרת, ברז כיבוי

התיאור נוצר באופן אוטומטי

Figure 2: ***TAUVEX mockup built by El-Op[[4]](#footnote-4)***

Professor Yuval Neeman of Tel Aviv University served as Chairman of the Israel space agency and was also responsible (administratively) to Tel Aviv University's TAUVEX science team. He approached the Soviet Union, which started to work on Spektr-RG (Спектр-РГ) – Roentgen-Gamma space telescope.

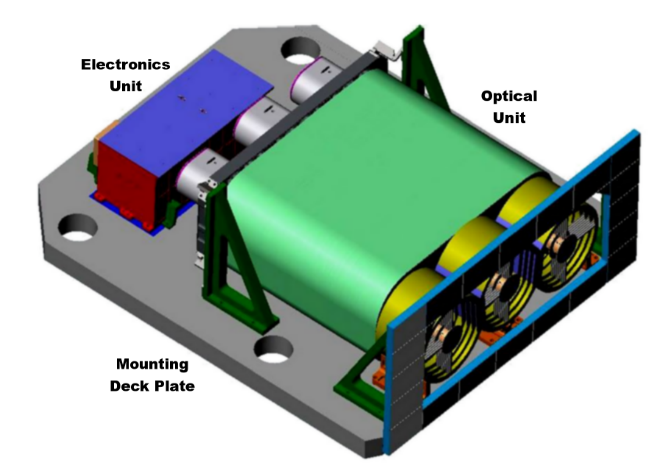


Figure 3: ***TAUVEX layout – Linear configuration of the three 20 cm diameter telescopes***.[[5]](#footnote-5)

The negotiation with USSR on the integration of TAUVEX on the huge Soviet space telescope was conducted by the Israel space agency, with the participation of the Tel Aviv University science team.

In June 1991 it was proposed that TAUVEX will be launched and operated from the Spectrum Rontgen-Gamma (**SRG**) spacecraft, as part of the SODART (Soviet-Danish Rontgen Telescope) experiment. The Israeli team was part of the Danish one, and was harmonistically referred to as "South Denmark team" in addition to "North Denmark" – the original Danish team.[[6]](#footnote-6) The SRG satellite was expected to be launched in late 1997 by the Russian Space Agency into a high elliptical orbit and including TAUVEX requires only a 0.5% increase in its mass and 2% in its power consumption.[[7]](#footnote-7)

תמונה שמכילה לוויין, תובלה, כחול, שולחן

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Figure 4: ***TAUVEX mounted on the Soviet (later Russian) SRG space telescope***

**TAUVEX Electronics Unit (EU)**

The Electronic Unit (EU) of TAUVEX contains 14 printed circuit cards. The different elements in the EU are analog front ends for the three telescopes, a doubly-redundant digital signal processor, a doubly-redundant central processor unit, power conditioning units, image buffer solid-state storage, two doubly- redundant disk storage units, and six high voltage power supplies. The mass of the EU is 14 kg, and it requires up to 25W to operate (and up to 20W for active temperature control). As the manager of TAUVEX project at EL-OP recalls, when Israel space agency held a meeting at NASA's Goddard spaceflight center, to consult with the Americans, NASA's scientists doubt the feasibility of the telescope due to its lightweight and small dimensions.[[8]](#footnote-8) (From day one, the telescope MUST have been small and lightweight, since it was originally designed to be fitted in an Ofek class satellite, and launched by the Shavit, Israel's light SLV.

**Integration in Russia**

During qualification tests of SODART, the construction was vibrated and shocked before being integrated with the whole SRG spacecraft. As preparation for this, at **NPO Lavochkin**, the TM of TAUVEX has been installed in its location on the sky side of SODART.

The TAUVEX TM is covered by its protective cover (manufactured by the **Babakin Science & Space Research Center**

El-OP team was working in Russia and put the TAUVEX TM (Technical Model) on the SRG.

תמונה שמכילה סירה, חוץ, מים, גדול

התיאור נוצר באופן אוטומטי

Figure 5: **TAUVEX technical model is mounted on the side of the Russian SRG space telescope**[[9]](#footnote-9)

Some of the tests for the TAUVEX telescope were conducted in Germany, per El-Op recommendations.[[10]](#footnote-10) These included thermal vacuum and vibrations test. At the time of TAUVEX's test the capability to conduct them was already available at the IAI (Israel Aerospace Industries, known then as Israel Aircraft Industries). It is POSSIBLE that TAUVEX needed some specific tests that IAI was unable to conduct, or that the infrastructure in Israel was occupied with one of the Ofeq satellites. The simulations demonstrated the compliance the thermal design and showed that TAUVEX will operate properly in the different environmental conditions within the operating envelope of SRG.

תמונה שמכילה ישיבה, שולחן, מזון, איש

התיאור נוצר באופן אוטומטי

Figure 6: **TAUVEX during environmental tests in Germany**

After YEARS of delays on the launch date of SRG, and continuous budget issues - the decision was made in Russia to cancel the mission. TAUVEX was once more on the ground with no valid option to be launched.

**Going to India**

The TAUVEX project was a major project of the Israel space agency, and it was feared -after cancellation of SRG – that it became a "white elephant". [[11]](#footnote-11) So other launch options were eagerly looked for. In December 2003, Israel and India signed an MOU with India's ISRO, and part of the agreement was the launching of TAUVEX by India.[[12]](#footnote-12) After years of storage, It was not without considerable ADDITIONAL funds that the telescope could be refurbished, and a new adaptor could have been designed and built In early 2003 ISA signed an agreement with the Indian Space Research Organization (ISRO) to launch TAUVEX onboard the Indian Technology-demonstrator satellite GSAT-4, which was about to be launched to a geosynchronous orbit. The orbit of the satellite was far from ideal for TAUVEX, and its field of view was not optimal. Further work was needed, and a special adopter was envisioned and built for the telescope, with motorized mechanism enabling it to toggle a little thus increase its field of view. This mechanism increased the telescope's field of view, without moving the satellite (which was not possible since it was a communication satellite, with the NADIR panel always looking towards Earth).

תמונה שמכילה ציור, שלט

התיאור נוצר באופן אוטומטי

Figure 7: **TAUVEX II logo**

Originally, TAUVEX was scheduled to be launched in 2008 but various delays caused the integration with GSAT-4 to take place only in November 2009 for a launch the following year.

The contract for TAUVEX II was awarded by Israel space agency to ELBIT systems LTD – ELOP division (ELOP was then part of ELBIT) on June 21, 2004.[[13]](#footnote-13) The contract is valued at approximately $3.5 million[[14]](#footnote-14).

תמונה שמכילה מעגל חשמלי

התיאור נוצר באופן אוטומטיFigure 8: **TAUVEX mounted on the side of Indian satellite GSAT-4**.[[15]](#footnote-15)

TAUVEX was in storage for years before the Indian launch option came to be.

It was imperative that as much of the original hardware will be used. This is reflected from the official documents, such as the one on figure 9 and 10.

תמונה שמכילה צילום מסך

התיאור נוצר באופן אוטומטי

Figure 9: ***TAUVEX program overview as of early 2004, after the contract with ISRO to launch it on GSAT-4 was signed*** [[16]](#footnote-16)

תמונה שמכילה צילום מסך

התיאור נוצר באופן אוטומטי

Figure 10: ***TAUVEX program overview as of early 2004, after the contract with ISRO to launch it on GSAT-4 was signed*** [[17]](#footnote-17)

ISRO decidedin January 2010 **to remove TAUVEX from the satellite** since the Indian-built cryogenic upper stage for GSLV was deemed under-powered to bring GSAT-4 to a geosynchronous orbit. This proved to be beneficial for TAUVEX since GSAT-4 and its launcher were lost on April 15, 2010 due to the failure of the carrier rocket’s 3rd stage.

On 13 March 2011 TAUVEX was returned to Israel and was stored at the Prime Contractor facility pending an ISA decision about its future.

תמונה שמכילה מקורה, אדם, שולחן, איש

התיאור נוצר באופן אוטומטי In **2012** ISA decided to **terminate the TAUVEX project**, although there was a valid opportunity to put TAUVEX on a stratospheric balloon. The TAUVEX was once again put on storage at EL-OP facility, and no further effort was made to find another launch opportunity for it. TAUVEX is still in storage, but during the years it was not kept as a space qualified hardware and some components deteriorated overtime.

**The TAUVEX archive**

During decades of researching Israeli space projects, one of the difficult aspects was to locate original materials, documents etc. Many times, these materials could not be traced for many reasons – from classification to negligence and lack of awareness of the historical importance of technical materials. Because of this, many subjects are doomed to remain in obscurity and we have secondary sources at best. This time it was completely different – the entire archive of TAUVEX project is accessible at its PI office – all the technical documents, meetings minutes, letters etc. are preserved by Dr. Noah Brosch of Tel Aviv University. Tens of thousands of pages in total – all on paper, archived by topics and dates. This is nothing less than amazing, in comparison with other early space projects in Israel. A digitation project is a vast undertaking and should be considered; And the sheer volume of documents and wealth of information could be the basis for a book on the project, not just a paper.

**Figure 11: Part of the TAUVEX archive at Tel Aviv University office of Dr. Noah Brosch (left) during a meeting with the author[[18]](#footnote-18)**

תמונה שמכילה מקורה, עמידה, איש, חדר

התיאור נוצר באופן אוטומטיAs the original TAUVEX is preserved at ELOP/ELBIT, it was as a surprise for me to find out that a full-scale mockup of TAUVEX is still exist, at the Tel Aviv University. The model is in a protective case, attached to the ceiling, and I literally unearthed it…from a thick, decade long cover of dust. In a future space museum, it will be a prominent piece of Israeli space history.

Figure 12: **TAUVEX mockup used during the development phase of the project, at the Tel Aviv University. In the picture, cleaned by the author.**

**The TAUVEX Legacy**

When TAUVEX was envisioned, the UV astronomy from space was still in its infancy, and the Israeli solution – using small aperture telescopes in various wavelength – was innovative and non-conventional. Since cancellation of the project, the field has changed dramatically, and the science gathered via UV observatories in space provide numerous scientific papers all over the world. It is understandable that TAUVEX itself will not make it into space, and it is now not only not qualified for spaceflight but outdated piece of technology.

However, Israeli academia is once more pursuing UV astronomy from space – this time the effort is led by the Weizmann Institute of Science, with support from Israel space agency and ELOP-Elbit – ULTRSAT.

ULTRASAT is a scientific mini-satellite carrying a telescope with an unprecedentedly large field of view (210 squared degrees) observing in the ultraviolet (220-280nm, UV). Its launch to geostationary orbit (GEO) is planned for 2023. ULTRASAT will revolutionize our understanding of the hot transient universe: the extra-Galactic volume, that will be accessible to ULTRASAT for the discovery of transient sources, is 300 times larger than that of the most sensitive UV satellite to date. One of the key science goals of ULTRASAT is the discovery of electro-magnetic emission following the detection of gravitational waves (GW) from the mergers of binaries involving neutron stars. Such detections will be the key to using these events for addressing fundamental physics questions, such as the origin of the heaviest elements and the expansion rate of the universe. [[19]](#footnote-19)

תמונה שמכילה קטן, שולחן, ישיבה

התיאור נוצר באופן אוטומטי

Figure 13: **Artist rendering of ULTRASAT[[20]](#footnote-20)**

The ULTRASAT spacecraft will be constructed by the Israeli Aerospace Industry (IAI), and the telescope will be constructed by Elbit/Elop.

ULTRASAT is jointly funded and managed by the Israel Space Agency (ISA) and the Weizmann Institute of Science (WIS), under the scientific leadership of the WIS, and with a significant contribution of the DESY center of the Helmholtz association. ULTRASAT is planned for a 3-year operation at a GEO orbit. Its small mass and volume, 160 kg and <1m3, allows a launch to GEO as a secondary payload.

1. From the author's archive [↑](#footnote-ref-1)
2. See Dany Shalom, "Over the horizon – 50 years of Israel in space", bAVIR publishing, 2004, pp 72-73 [↑](#footnote-ref-2)
3. ELOP is the sole provider of the telescopes in all Israeli built satellites [↑](#footnote-ref-3)
4. Scanned from a 1991 brochure issued by EL-OP, from the author's archive [↑](#footnote-ref-4)
5. Compare with original design in figure 1. Drawing from a presentation of TAUVEX project in Bangalore, India, by joint India-Israel science team, 2003 [↑](#footnote-ref-5)
6. An interview with Dr. Noah Brosch on September 15, 2020 at his Tel Aviv university office [↑](#footnote-ref-6)
7. Ibid [↑](#footnote-ref-7)
8. An Interview with Opher Braun, September 20, 2020 [↑](#footnote-ref-8)
9. Image courtesy of Tel Aviv University [↑](#footnote-ref-9)
10. At iABG [↑](#footnote-ref-10)
11. As stated by Aby Har Even, a 10 years director of Israel Space Agency wrote – Israel in Space - strategic aspects, BESA Center, Bar Ilan University, July 2006, p.3 [↑](#footnote-ref-11)
12. See "Israel civilian space program – cooperation with other countries" by Aby Har Even, BESA center, Bar Ilan University, May 2009, p. 12. [↑](#footnote-ref-12)
13. http://media.corporate-ir.net/media\_files/irol/61/61849/Press/2004/Jun22.pdf [↑](#footnote-ref-13)
14. Ibid [↑](#footnote-ref-14)
15. ISRO rendering [↑](#footnote-ref-15)
16. From “***Configuration & Upgrades Review*** *–* ***September 1994***” report (author’s collection) [↑](#footnote-ref-16)
17. Ibid [↑](#footnote-ref-17)
18. Pictured on September 15, 2020 [↑](#footnote-ref-18)
19. For more on ULTRASAT see: https://www.weizmann.ac.il/ultrasat/home-0 [↑](#footnote-ref-19)
20. From Israel space agency website: https://www.space.gov.il/en/research-and-development/1129 [↑](#footnote-ref-20)