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THE STUDENTS WHO SAVED THE WORLD: PROJECT ICARUS (1967)

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ABSTRACT

Project Icarus (1967) was a landmark student-led system engineering study at Massachusetts Institute of Technology (MIT) that pioneered the concept of planetary defense. The project was initiated by Professor Paul Sandorff to address the existential threat posed by the near-Earth asteroid 1566 Icarus, which was predicted to pass perilously close to Earth in June 1968. Students were tasked with developing a complete, time-constrained plan to prevent a catastrophic impact using only existing space technology. The resulting plan proposed launching six modified Apollo Command/Service Modules, each carrying a 100-megaton nuclear warhead, via Saturn V rockets. The strategy involved detonating the warheads near the asteroid's surface to use the radiation's momentum to bump Icarus off its collision course. The student teams determined that deflecting an asteroid at its farthest point from the Sun (aphelion) was the optimal action, but the 1968 timeframe obligated a very soon near-Earth interception. The proposed multi-mission strategy acknowledged the possibility of fragmentation, with subsequent warheads targeting the largest pieces. Costing an estimated US$ 7.5 billion, the study projected a 71.4% probability of complete success in preventing a disastrous impact. Though the asteroid passed safely close to Earth, Project Icarus is recognized as a profound early precedent for the "planetary defense" missions now overseen by agencies like NASA.

RESUMEN

Los estudiantes que salvaron al mundo: El proyecto Ícaro (1967)

El Proyecto Ícaro (1967) fue un estudio pionero de ingeniería de sistemas, liderado por estudiantes del MIT, que sentó las bases del concepto de defensa planetaria. El profesor Paul Sandorff lo inició para abordar la amenaza existencial que representaba el asteroide 1566 Ícaro, cuyo paso peligrosamente cerca de la Tierra se preveía para junio de 1968. Los estudiantes recibieron el encargo de desarrollar un plan completo, con plazos definidos, para prevenir un impacto catastrófico utilizando únicamente la tecnología espacial existente. El plan resultante proponía el lanzamiento de seis módulos de comando y servicio Apolo modificados, cada uno con una ojiva nuclear de 100 megatones, impulsados mediante cohetes Saturno V. La estrategia consistía en detonar las ojivas cerca de la superficie del asteroide para aprovechar el momento de la radiación y desviar a Ícaro de su trayectoria de colisión. Los equipos de estudiantes determinaron que desviar el asteroide en su punto más alejado del Sol (afelio) era la acción óptima; sin embargo, el plazo de junio de 1968 exigía una intercepción muy rápida y cercana a la Tierra. La estrategia propuesta de misiones múltiples reconocía la posibilidad de fragmentación, por lo que se consideraron ojivas posteriores dirigidas a pulverizar los fragmentos más grandes. Con un coste estimado de 7500 millones de dólares, el estudio proyectaba una probabilidad del 71,4% de éxito total en la prevención del catastrófico impacto. Aunque el asteroide pasó cerca de nuestro planeta sin incidentes, el Proyecto Ícaro se reconoce como un precedente fundamental para las misiones de «defensa planetaria» que ahora supervisan agencias como la NASA.

Palabras clave: Ícaro, asteroide, impacto, intercepción, Sandorff, fin del mundo.
Keywords: Icarus, asteroid, impact, interception, Sandorff, doomsday.

INTRODUCTION

This is the fascinating history of Project Icarus (1967), a pivotal student-led engineering study at Massachusetts Institute of Technology (MIT) that addressed the existential threat of an asteroid collision, setting an early precedent for the concept of planetary defense.

THE THREAT OF ICARUS

In Greek mythology, Icarus refers to the mythological son of Daedalus, known for flying too close to the Sun with wings his father built. Daedalus, the architect of the labyrinth of Crete, warned his son not to fly too high or too low. However, Icarus ignored him, and the Sun melted the beeswax on his wings, causing him to fall into the sea and drown (CHALIAKOPOLUS 2025).

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On June 10, 1949, the German astronomer Walter Baade (1893-1960) accidentally discovered the asteroid that would be known as 1566 Icarus. It was quickly clear that the orbit of Icarus not only carried the asteroid near the Sun (hence its name), but also close to the Earth (OHTSUKA *et al.* 2007). In 1965, Robert S. Richardson (1902-1981), an American astronomer who had helped calculate the orbit of Icarus, pointed out that it would take only a tiny change in the asteroid's orbit for it to strike the Earth during its 1968 approach (RICHARDSON 1965). The Australian nuclear physicist Stuart Thomas Butler (1926-1982), from the University of Sydney, then warned that Icarus "could reduce any of the world's major cities to rubble in a flash."

Walter Baade used the 48-inch reflecting telescope at Palomar Observatory (Caltech) in southern California to capture the first image of asteroid 1566 Icarus on June 26, 1949. Icarus appeared as a streak against a field of stars on a glass photographic plate. Icarus was soon found unusual, because its highly elliptical orbit takes it from the inner edge of the Main Asteroid Belt between the orbits of Mars and Jupiter to well within Mercury's orbit. Like its mythological namesake, it swoops closer to the Sun (only 27.3 million kilometers away) than almost any other planetary body of the solar system (RICHARDSON 1965), but today we know that asteroid 2021 PH27 flies even closer to the Sun. Icarus needs 409 days (1.12 years) to circle the Sun (GREENBERG *et al.* 2017).

In its journey, Icarus orbits the Sun once every 13 months, and it moves close to the Earth's orbital path during June every 9, 19, or 28 years, when the two bodies reach their point of closest approach. At this point, they typically pass each other at a relative velocity of 24-34 km/s. Baade detected Icarus during one of these close encounters (**Figure 1).** Astronomers have charted its current orbit, but they also recognize that a shift of only a few degrees in the position of the descending node of the asteroid's orbit could potentially place it on a collision course with our planet (RICHARDSON 1965).

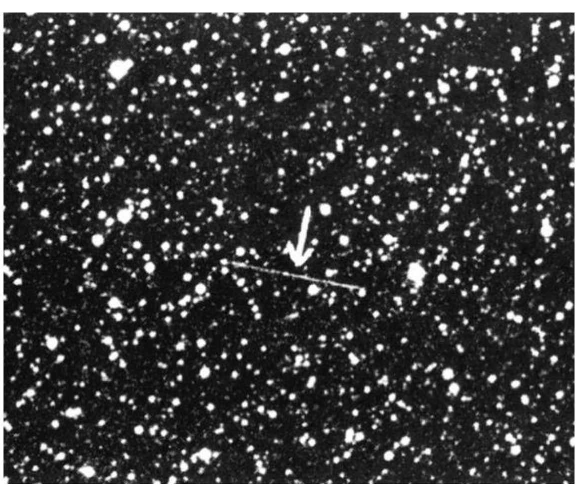

Figure 1*. Icarus appears as a streak (marked) in this long-exposure first photograph.* Source: https://www.phy.olemiss.edu/~luca/astr/Topics-Solar/Asteroids-N.html

THE MIT CHALLENGE

During the spring term of 1967, at the Massachusetts Institute of Technology (MIT), Professor Paul Edwin Sandorff (**Figure 2**), taught the Interdepartmental Student Project in Advance Systems Engineering. Sandorff prepared a graduate course (**Figure 3, 4**) on advanced space systems engineering, the year before an asteroid named Icarus made its approach to our planet. The professor tried to capitalize on the sensational headlines, to create a pioneering project he called "Mission to Icarus." He posted across the MIT campus several advertisements on bulletin boards, looking for potential interested students. The professor stated in this advertisement that his course would require the participants to develop a full, detailed proposal for preventing the impact of Icarus on Earth.

Figure 2*. Professor Paul E. Sandorff portrait.* Source: https://mitmuseum.mit.edu/collections/object/GCP-00021198

Sandorff provided a detailed project description, proposing a hypothetical problem to be solved by his class in advanced systems engineering: assuming that asteroid Icarus will collide with our planet. More specifically, he stated that at approximately 12:26 p.m. on June 19, 1968, the asteroid Icarus, roughly a mile in diameter, would impact the ocean, probably the mid-Atlantic, about 1,600 kilometers east of Bermuda. The impact would be the equivalent of 500,000 megatons of TNT, forming a crater 16-25 kilometers across on the ocean floor. Tidal waves 30 meters high would wash across coastal cities (including the MIT campus), causing worldwide effects, and some earthquakes dozens of times worse than any ever recorded in the world. If the strike occurred on land, the blast would throw dust into the stratosphere, reducing the solar radiation, potentially triggering a new ice age. The message was clear: Icarus must be stopped. No efforts or expenses will be spared, and the only and crucial limitation being time. The program had to use existing space technology and hardware (Gemini and Apollo), as well as national and global resources that could realistically be mobilized in a 70-week timeframe. Above all, it had to succeed (MIT STUDENT PROJECT IN SYSTEMS ENGINEERING 1968). Sandorff gave his class until May 23, 1967, to develop a plan to avert the catastrophe.

Because the physical characteristics of Icarus were poorly understood in 1967, Sandorff and his students had to make several assumptions and estimates, such as modelling the asteroid as a 1,280 meters body in diameter, with an average density of 3.5 g/cm^3 (for comparison, Earth has an average density of 5.51 g/cm^3). This resulted in a calculated mass of 4.4 billion tons. The following chapters summarize some of the technical work and conclusions achieved by Professor Sandorff and his students, later published as: MIT STUDENT PROJECT IN SYSTEMS ENGINEERING – Project Icarus (1968).

THE PROJECT ICARUS

Assuming the premise that the Icarus disaster was real, the MIT students organized themselves into seven groups totaling 21 students. The groups were divided into: Orbits and Trajectories, Nuclear Payloads, Boosters and Propulsion, Spacecraft, Guidance and Control, Communications, Economics and Management. In addition to this unique learning experience, they were privileged to have an impressive lineup of nine experts lecturing along those weeks. They also established numerous contacts with leading physicists and astronomers, utilized MIT facilities, computers, libraries, and determined whether Cape Kennedy's facilities and capabilities could be expanded in time for a project of this magnitude. The students' plan relied entirely on the new Saturn V rocket technology. Each group elected a leader to define system interfaces with other teams, and established internal guidelines. The groups then coordinated themselves, in order to use systems engineering to devise a master plan to face the ominous threat of Icarus.

Because MIT was then deeply involved in the Apollo program at that time, in March 23, 1967, the students had a two-day opportunity to visit Cape Kennedy in Florida to consider and evaluate the U.S. space capabilities. After seeing the giant structures NASA had built to launch astronauts to the Moon, this visit erased any doubts about using Apollo/Saturn technology in their Icarus project. Even though the first successful Saturn V Moon rocket test flight would not occur until later, on November 9, 1967.

After 15 long and exhausting weeks of frenetic calculations and planning, Sandorff's and his group of 21 senior and graduate engineering students (Fletcher, Heldt, Marantz, Hukai, Seth, Flynn, Mbanefo, Suzuki, Deichman, Jones, Lange, Lindley, Wagner, Bentley, Kalla, Kleiman, Labrecque, Tenny, Rose, Wolejsza and Baughman) finalized a complex master plan that they believe would save the world from a doomsday.

Figure 3. *MIT classroom with Professor Paul Edwin Sandorff lecturing.* Source: https://mitmuseum.mit.edu/collections/object/GCP-00021204

Figure 4. *Professor Paul Edwin Sandorff instructs students in a classroom. Two model rockets are displayed next to him over his desk.* Source:https://mitmuseum.mit.edu/collections/object/GCP-00021198

THE PROBLEM AND STRATEGY

The students rapidly achieved significant insights into the mitigation challenge presented by an inbound asteroid. They determined that the orbital mechanics favor deflecting a collision-course asteroid when it is intercepted at its aphelion (the point in its orbit farthest from the Sun). At this specific orbital parameter, the asteroid's heliocentric velocity is at its minimum, meaning that the required Δv (change in velocity) necessary for effective trajectory modification is minimized, thereby optimizing mission efficiency and results.

The students concluded that early detection is the paramount prerequisite for preventing the collision of an asteroid with our planet. If a potentially hazardous asteroid could be spotted many years before impact, a deflection mission could be launched to intercept that body when its orbit is distant from the Sun's gravitational influence. By giving it a modest "push", the rocket would change the asteroid's orbit slightly. Over several years, that would be sufficient to ensure the asteroid misses Earth's orbital path, thereby precluding any impact event.

However, for Icarus in 1968, it was too late. Under this extremely difficult time constraint, a soft landing or even low-speed impact to deposit rockets or explosives on Icarus was found to be impossible, as the asteroid would be hurtling toward Earth at over 100,000 km/h. Furthermore, total destruction with a single hydrogen bomb was ruled out as a possibility because it would have required a billion-ton-yield bomb (50 times larger than the U.S. arsenal at that time) and risked shattering Icarus into a devastating "shotgun blast" of fragments. The only viable option remaining was deflection or controlled fragmentation using nuclear blasts near Earth.

THE PLAN OF ATTACK

The proposed solution by the MIT students involved launching six heavily modified Apollo Command/Service Modules (from the active Apollo program), each carrying a massive nuclear warhead with an estimated theoretical yield of 100 megatons of TNT. These "Interceptors" (**Figure 5),** would be launched by the powerful Saturn V rockets, with only minimal modifications. The conceptual Icarus spacecraft would have consisted of an Apollo Service Module (SM) with a five-foot cylindrical extension known as the Payload Module (PM) at the top (**Figure 6**). Instead of the standard Command Module, the top of the stack would be a simple aluminum cone containing only the necessary telemetry systems. The PM would have carried the nuclear bomb weighing 18,150 kilograms, shaped as a cylinder, and mounted horizontally along the diameter of the spacecraft. One side of the PM would feature a phased-array radar antenna for tracking and rendezvous with the Icarus asteroid.

The six Saturn V rockets would be guided by radar, and the first bomb would detonate about 30 meters from the asteroid, far enough to minimize the risk of fragmentation. Radiation from the blast would vaporize the asteroid's surface, creating a jet of material that would provide the momentum necessary to nudge the asteroid off course. If Icarus was still heading for our planet, subsequent interceptors would keep pushing Icarus off course or destroy any potentially dangerous fragments left.

Following the master plan, the first Saturn V rocket (called Saturn-Icarus 1) would lift off from Cape Kennedy on April 7, 1968, exactly 72.9 days before the predicted impact with Earth. Its payload module, the "Interceptor 1", would reach Icarus 60 days later, when the asteroid was located 12.9 days and 32.2 million kilometers from Earth. By the time "Interceptor 1" reached its target, the MIT Lincoln Laboratory's Haystack radar would have detected Icarus for the first time.

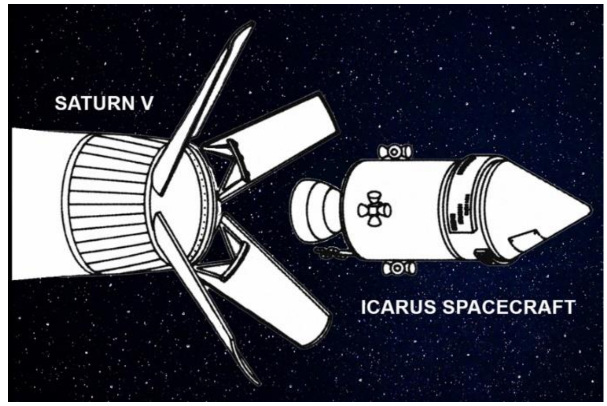

Figure 5. *Icarus spacecraft at separation from the Saturn V upper stage.* Source: Modified from MIT (1968).

The Saturn-Icarus 2 would have launched on April 22, 1968, 58.3 days before Icarus was due to collide. "Interceptor 2" would have reached its target 24.9 million kilometers from Earth, and 9.9 days before impact, repeating the same operation as Saturn-Icarus 1. Saturn-Icarus 3 would have lifted off on May 6, 44 days before Icarus was due to arrive, and its "Interceptor 3" would have reached Icarus one week later and 17.3 million kilometers from Earth, or 6.9 days before impact. Saturn-Icarus 4 would have lifted off on 17 May 1968, 32.7 days before Icarus' arrival, and "Interceptor 4" would have reached the asteroid 28 days later, when Earth and Icarus were only 12.4 million kilometers apart or 4.9 days before impact.

Following the tight and precise schedule, Saturn-Icarus 5 would have left Earth on June 14, 1968, only 4.9 days before the projected doomsday. "Interceptor 5" would have reached Icarus about 2.26 million kilometers out from Earth, just 21.6 hours before collision. At that time, the asteroid would have appeared as a modest star in the sky near the Orion constellation. Saturn-Icarus 6, the final shot if needed, would be launched on June 14 (a few hours after Saturn-Icarus 5) and would have intercepted Icarus just 2.01 million kilometers away, barely 19 hours before the asteroid rendezvous with our planet.

The terminal phase of each interceptor begins when the optical sensor acquired the asteroid's proximity, about three hours before the rendezvous. At this moment, trajectory corrections would be made to achieve the necessary accuracy. When each interceptor reached a distance of 170 meters from Icarus, about four minutes before rendezvous, the radar would have detected the asteroid, supplying information for final correction maneuvers. Five seconds before impact, a fusing radar would acquire the asteroid closest proximity, arm the bomb and trigger the nuclear device at a distance of approximately 30 meters. The students' plan could not determine the exact net effect the explosion would have had on the asteroid's course, but they estimated that each blast would alter the asteroid's velocity by between 8 and 290 m/s. Assuming that the first mission might not be perfect, each subsequent launch would provide an opportunity to evaluate, understand, and make the necessary corrections to ensure success. The MIT students acknowledged in their plan that

Icarus might break into smaller fragments after a detonation. In that plausible scenario, subsequent interceptors would be redirected to target the largest and most dangerous fragments. If fewer than six explosions proved sufficient to deflect the asteroid, then the remaining Saturn V rockets and their Interceptors would not be deployed.

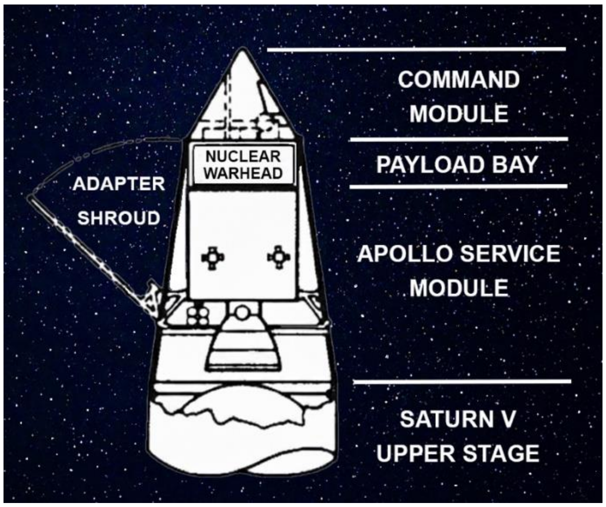

Figure 6. *Apollo Service Module configuration.* Source: Modified from MIT (1968).

For each nuclear device launched by a Saturn V on an intercept mission, the MIT students also designed a monitoring system, to observe and record the results of every encounter. This system, independent but parallel to each interceptor, was named: Intercept Monitoring Satellite (lMS). The IMS would be launched by an Atlas-Agena booster, the same reliable vehicle used for the first five Mariner unmanned probes to Venus and Mars, as well as the Ranger and Lunar Orbiter unmanned probes to the Moon. The calculated trajectory would place each IMS close to the intercept point at the time of every detonation, but far enough to avoid radiation damage and escape collision with any large fragments resulting from the explosion.

CONCLUSION AND LEGACY

On May 22, 1967, the students presented their complete plan during a three-hour summary (rehearsed twice before the final show), at MIT's Kresge Auditorium's Little Theater. The event had an audience of aerospace academics and representatives from major national news services. This exposure sparked a nationwide media frenzy, with sensational headlines appearing in dozens of major newspapers across the country from coast to coast. Even TIME magazine featured a small article in its "Science" section (June 16, 1967; pages 54-55), describing Project Icarus after interviewing the MIT participants.

Following Icarus's safe passage by Earth in 1968, public attention to the impact risk waned. Unfortunately, there was a noticeable lack of government initiative to establish funding for detection programs essential for the future interception and deflection of hazardous asteroids.

Professor Sandorff's class estimated that Project Icarus would cost about $7.5 billion. They also calculated that the chance of merely fragmenting the asteroid was very low, about 1.5%. However, if this happened, then the asteroid might cause more widespread damage to Earth than an impact intact. Most importantly, the estimated probability of success, either completely deflecting the "doomsday" asteroid or preventing any significant part of the asteroid from reaching Earth was roughly 71.4% using the six-mission strategy. At that time, completing the project would have required no more than 1% of USA's GDP.

During the closest approach on June 19, 1968, Icarus became the first asteroid detected using Earth-based radar, with measurements obtained at the Haystack Observatory (MIT). Scientists have since determined that asteroid 1556 Icarus is roughly spherical and rotates rapidly, approximately once every 2,273 hours (OHTSUKA *et al.* 2007). It is classified as an S-type asteroid (siliceous mineralogical composition), composed primarily of stony materials, and measuring about 1,440 meters across. Its density is estimated at roughly 2.5 g/cm^3. The closest approach of Icarus to Earth since 1968 will occur on June 14, 2090 (GREENBERG *et al.* 2017).

The lasting legacy of Project Icarus is profound. It was a pioneering engineering study that, 59 years ago, first formalized the steps required to mitigate an asteroid threat. Since 1980, when Luis Alvarez, Walter Alvarez, Frank Asaro, and Helen Michel (ALVAREZ *et al.* 1980) presented evidence of a large asteroid impact (Chibxulub), as the cause of the Cretaceous-Paleogene extinction that doomed the dinosaurs, there has been an increased awareness that our planet exists in a state of constant cosmic bombardment. In June 1994, when the fragments of the comet Shoemaker-Levy 9 astonished the public by colliding with Jupiter, the US Congress officially incorporated impact prevention or "planetary defense", as it is now called, into NASA's core responsibilities.

In 2016, NASA established the Planetary Defense Coordination Office (PDCO) to manage the agency's ongoing mission of finding, tracking, and understanding potentially hazardous asteroids and comets (NASA 2025). Today, these efforts continue with missions like the NEO (Near Earth Object) Surveyor mission, a space-based infrared telescope expected to launch in late 2027 or early 2028. This mission will be particularly effective at finding dark carbon-rich asteroids that are difficult to detect with ground-based telescopes. The goal of the NEO Surveyor is to find and catalog more than 90% of the potentially hazardous asteroids (PHAs) larger than 140 meters, and calculate the probability of any impact over the next century (MAINZER *et al.* 2023).

As curious final note, the original Project Icarus report served as the basis and inspiration for the 1979 science fiction film "Meteor", starring Sean Connery, Natalie Wood, Martin Landau, and Henry Fonda.

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