SOPRONI
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FAIPARI MÉRNÖKI ÉS
KREATÍVIPARI
KAR

AZ ALKALMAZOTT MŰVÉSZET LÉTMÓDJAI ÉS A KREATÍV IPAR KIHÍVÁSAI NAPJAINKBAN

Faipari Mérnöki és Kreatívipari Kar Tudományos Kiadványa

Szerkesztette: Márfai Molnár László és Pásztory Zoltán

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SOPRONI EGYETEM KIADÓ

SOPRON, 2023

A kötet első 12 írása a Sopronban 2022. október 28-án *Az alkalmazott művészet létmódjai napjainkban* címmel megrendezett tudományos konferencia előadásainak szerkesztett anyagát tartalmazza.

A konferencia támogatói:

MTA VEAB Soproni Tudós Társaság Művészeti és Irodalomtudományi Szakbizottság

Magyar Tudományos Akadémia VEAB Képzőművészet, Művészetelmélet és Design Munkabizottság

Soproni Egyetem Faipari Mérnöki és Kreatívipari Kar

Felelős kiadó: Prof. Dr. Fábián Attila

a Soproni Egyetem rektora

Szerkesztette:

Dr. Márfai Molnár László és Dr. Pásztory Zoltán

Lektorálta:

Dr. Börcsök Zoltán

ISBN 978-963-334-453-8 (pdf)

https://doi.org/10.35511/978-963-334-453-8

Tartalom

Művészeti szekció

Műszaki szekció

Foregin languages section

Developing Info-Droplets to model the dark flight phase of meteorite fall

**Agota Lang, Matyas Bejo, Benke Hargitai, Barnabas Molnar,
Aron Sztojka**

Agota Lang, Instructor, University of Sopron, Faculty of Wood Engineering and Creative Industries, Institute of Wood Technology and Technical Sciences,
email: lang.agota@uni-sopron.hu
Matyas Bejo, Student, Obuda University, John von Neumann Faculty of Informatics,
email: bejomatyi@gmail.com
Benke Hargitai, Student, University of Freiburg, Faculty of Engineering,
email: hargitai.benjoe@gmail.com
Barnabas Molnar, Student, Budapest University of Technology and Economics, Faculty of Electrical Engineering and Informatics, email: molnar.barnabas.01@gmail.com
Aron Sztojka, Student, Federal Secondary College of Engineering Eisenstadt,
email: nargame12@gmail.com

DOI: https://doi.org/10.35511/978-963-334-453-8.Lang_A-et-al

Abstract

Existing models of meteorite fall are difficult to validate, since actual observations of the dark flight trajectory are unavailable. The study presented here aims at developing so-called ‘Info-Droplets’ that can be ejected at altitude and physically simulate the flight of meteorites. Four phases of the Droplet hardware and software development are described, along with the learnings of each test. Final phase testing and the development of the casing for free-fall testing are underway.

Introduction

Meteorites offer large quantities of interesting and useful information regarding the formation of the Earth, the Solar System or life, but for their research, they have to be found first. This is not an easy task as these objects only glow in the upper layers of the atmosphere and after that, there is no information about their locations. The latter phase of meteorite fall is referred to as ‘dark flight’.

Some meteorites burn up completely in the atmosphere before reaching their terminal velocities owing to their small size or porous structure, while others glow all the way down to the ground. The majority of all meteorites are not in either of these categories, though. They glow after entering the atmosphere and air resistance decelerates them continuously. After a short period, air resistance stops heating them enough to make them glow. This makes their recovery exceedingly difficult, even though they are of the utmost interest and importance to scientists (Walla 2018).

There have been several successful attempts to recover meteorites and meteorite fragments based on meteoric flight observed by camera networks. Several networks have been used historically, beginning with the Harvard photographic meteor program (Jacchia and Whipple 1956), with the first observed and recovered meteorite being Příbram from the Czech Fireball Network in 1959 (Ceplecha 1961). The determination of the so-called strewn field (the area where meteorite fragments may have landed) has many difficulties due to weather phenomena (esp. wind effects). Early studies relied on laborious hand calculations of numerical integration.

With the advent of computers, increasingly sophisticated mathematical models have been developed that are capable of faster and more precise calculations of the impact location. Recent studies on the subject include those of Vinnikov et al. (2016), Moilanen et al. (2021) and Towner et al. (2022), among others. These studies typically rely on numerical simulation with a number of assumption regarding especially the shape, mass and density of the meteorite, which affect the aerodynamic drag phenomena during the dark flight phase. This often causes errors of various magnitude in the prediction. Also, as Towner et al. remarks: “This dark-flight calculation is also difficult to verify. By the very nature of dark flight, there are no observations to cross-check during descent, so the only criteria for successful modelling are location and characteristics of a recovered meteorite, and a failure to recover may be caused by factors unrelated to the dark flight.” (Towner et al. 2022, p1) The study presented in this paper seeks to address this problem.

A team of researchers in the Baja Observatory, Hungary, has long been interested in ‘meteorite hunting’, i.e. finding meteorites crashed in the region (Vizi et al. 2016), but has been hampered due to the above difficulties. They are working on their own dark flight calculator model to predict the impact location of meteorites. The validation of the model requires experiments using physical models that can be dropped at altitude, and their flight monitored all the way up to the time of impact.

The University of Sopron hosts the ‘Soprobotics workshop’, a team of local high school students interested in robotics. They worked on and presented several projects at various conferences and competitions. This is where they met and formed a co-operation with dr. Tibor Hegedűs, the director of the Baja Observatory.

The aim of the presented study is the development of appropriate instruments for the validation of the ‘the dark flight calculator code’ developed by the Baja Observatory team.

For this purpose the Soprobotics workshop is working on developing and programming compact data-collection devices that can be enclosed in small spheres. The falling trajectories of the spheres – called Info Droplets – are analogous to those of meteorites in the phase of dark flight.

The Info Droplets need to satisfy a number of requirements. They need to be as small as possible. They should include appropriate instrumentation that allows the geographical tracking of the droplets throughout their flight. They also need to be durable and robust enough to protect the expensive electronics upon impact, so that they can be reused for subsequent measurements.

Materials and methods

The development of the Info Droplets started in 2017, and went through several iterations. Each phase of development was followed by test flights. Unfortunately, the pandemic situation significantly hindered testing, which is why experiments take a very long time. The following sections describe the hardware configuration of each version, the software architecture used for programming, and the test flights.

Hardware

A WEMOS D1 mini pro microcontroller is used to control of the device. The most important tool of measurement is a GPS module, which supplies the data required by the observatory team. The collected data is stored on an SD card which has its own shield. The unit is powered by a 3.7V LiPo battery.

The evolution of the droplets went through the following phases (see Fig. 1):

Phase 1: this device consisted only of the microcontroller, an SD-Card shield and an OCTOPART GPS which was provisionally connected with wires. This GPS only works up to an altitude of 18 km as a built-in limit, and, as such, was insufficient for our purposes.

Phase 2: The GPS was replaced by a UBLOX-NEO-M8Q which does not have the previously discussed height limit. This was planted on a custom PCB. For the additional functionality of Droplet-Droplet and Droplet-Ground communication, a LoRa RFM 95W radio module was added. This offers help in finding the droplets after a flight and supplies a log of measured data in case a unit should be lost or destroyed.

Phase 3: Further test flights revealed potential improvements which were duly implemented. A new, active GPS antenna was added, the GPS shield was redesigned to include the LoRa as well, a port was included for the GPS antenna and a battery-control shield was added for constant supply-voltage and charging capabilities.

Phase 4: Unreliable radio coverage forced us to switch to a commercial whip antenna for our LoRa communications

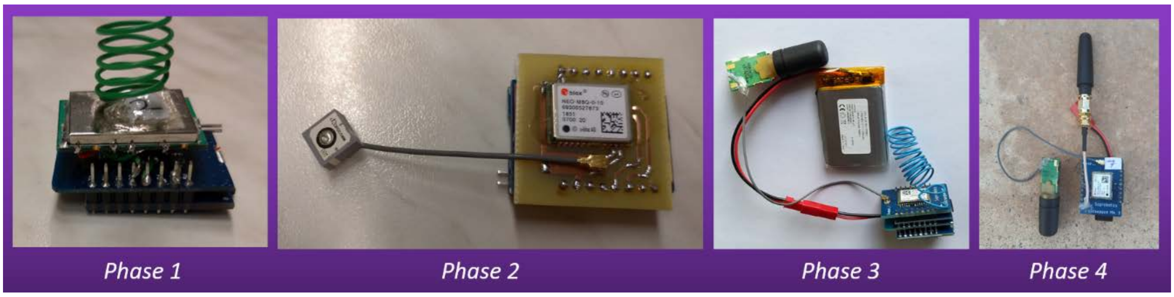
Phase 1 Phase 2 Phase 3 Phase 4

Fig. 1 – The four phases of Info-Droplet development

After each of the first three development phases, test flights were carried out, using a weather balloon, which carried the equipment up to an altitude of approx. 30 km. The instruments were housed in an expanded polystyrene (EPS) box ('gondola') with packing peanuts for extra protection. The weather balloon popped at altitude, and a parachute opened that carried the gondola to the ground. The testing of the fourth phase was postponed due to the pandemic situation, and is yet to be carried out.

Software

We programmed the microcontrollers in the Arduino IDE. For the GPS we used the TinyGPS++ library and the radio modules had their own library. This did not support the ESP based boards, but we could modify it, so the two devices can work together. The data collected during the fall is easy to import and analyse in a spreadsheet program.

Fig. 2 shows the operation sequence of the software. The features of the program are described below:

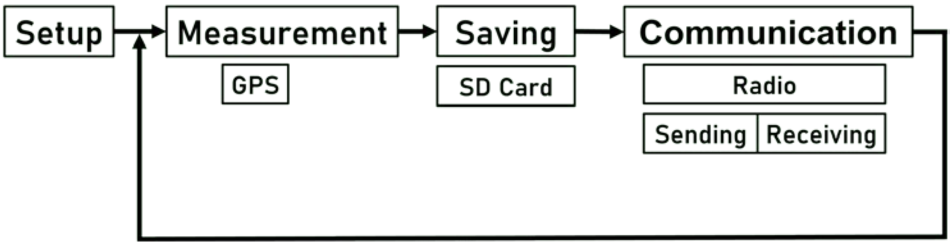

Fig. 2 – The sequence of operations in the Info-Droplet control

Code structure: Switching on the droplet initiates the setup sequence, which starts every module (SD card, Radio, GPS). In the main loop, the program reads the GPS coordinates, and stores the data on the card. Then starts the communication via radio with the other droplets as well as the ground unit.

Setup: The setup initiates several fundamental processes. To distinguish between the droplets, each device has a unique identifier. This is done based on the ID of the ESP module’s wifi chip. This means that we don’t have to change the code for each droplet. Basic information to collect includes: GPS communication pins, droplet ID, droplet version, software version, etc.

Next, the setup starts the radio and the GPS. Both modules use SPI, we can select the one we are using through its chip selector pin. After everything is ready, we can start the main loop.

Main loop: Firstly, we are measuring with the GPS and saving it in the data variable. This includes the droplet ID, the number of satellites it accessed, time, latitude, longitude and altitude. For safety purposes the same data is recorded into two files simultaneously (redundant data storage).

The first part of the communication is the sending of the data variable to the other droplet and to the Earth unit. The second part is the receiving and saving the data it receives from the other droplets.

Additional features: If the GPS loses its signal, the droplet detects and restarts it. We can also send some commands from the ground unit to the droplet via radio. We can restart the whole device, restart the GPS, restart the Radio, get the file version and wipe the whole SD card remotely.

Results and discussion

Each test carried out after the respective development phase provided important learnings for the further development of the Info Droplets as well as their programming. These are summarized in the followings:

Phase 1, August 2018: Fig. 3 shows the diagram generated from the recorded data. Apparently, both the climb and the fall was well documented, but the part of the flight above 18000m altitude is missing owing to the GPS’s built in limitation. This lead to incorporating more sophisticated GPS instrumentation.

Phase 2, September 2019: This was the first flight where we used radio communication. Unfortunately, the software could not separate the data from the various Droplets, and thus the values could not be evaluated. This pointed to the need to include unique identifiers for each Droplet.

Phase 3, June 2020: This test had a promising start, but unfortunately the GPS modules crashed after a period of time, and the satellite communication was severed. The diagram on Fig. 4 shows an increase in altitude to approx. 12 km, after which the signal stopped refreshing. This was not caused by an altitude cut off similar to Phase 1, as the UBLOX GPS was used, but rather the crashing of the GPS modules. Although radio communication between Droplets and to the ground unit was active, we could not solve the problem at that time.

The exact cause of the GPS units crashing could not be established, but, as all units crashed simultaneously, it is probably due to some atmospheric or cosmic radiation phenomenon. To avoid such problems in the future, the programming needed to be amended to allow restarting the GPS and other parts of the Droplets remotely. Unfortunately, due to the COVID 19 pandemic, no further experimentation could be conducted to date. Hopefully, the next phase of testing will reveal no further problems with the instruments and programming, and the Info Droplet electronics will be ready to be deployed to simulate meteorite fall.

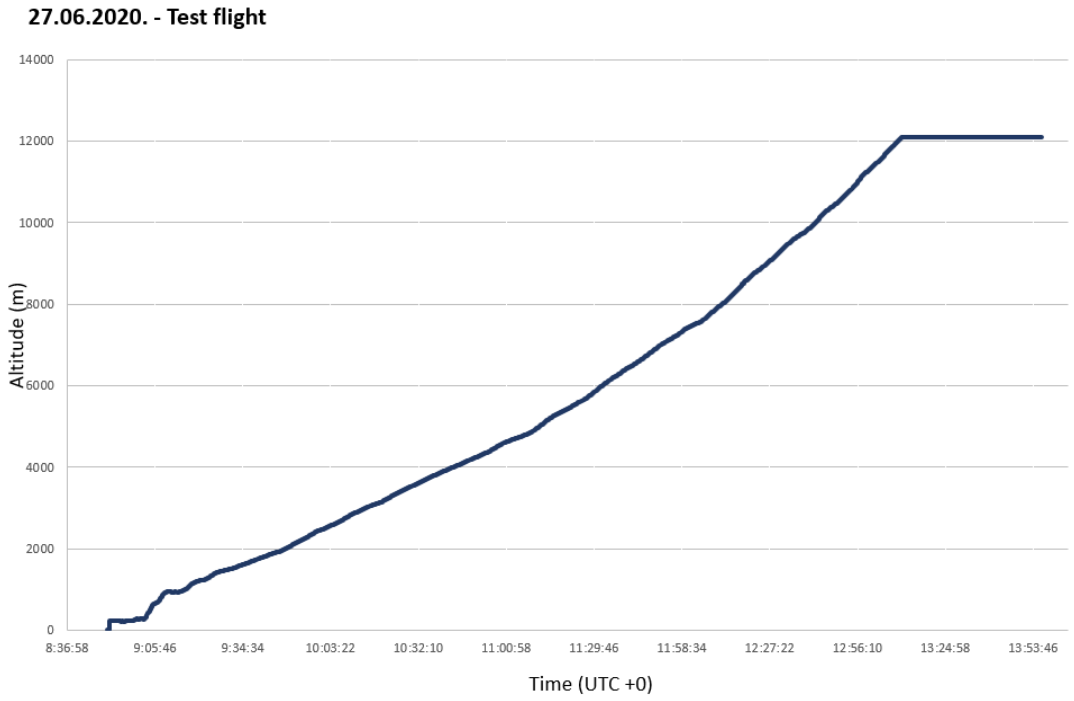

Fig. 3 – Altitude data collected in the first experiment. The plateau at 18 km is due to the limited altitude range of the GPS instrument

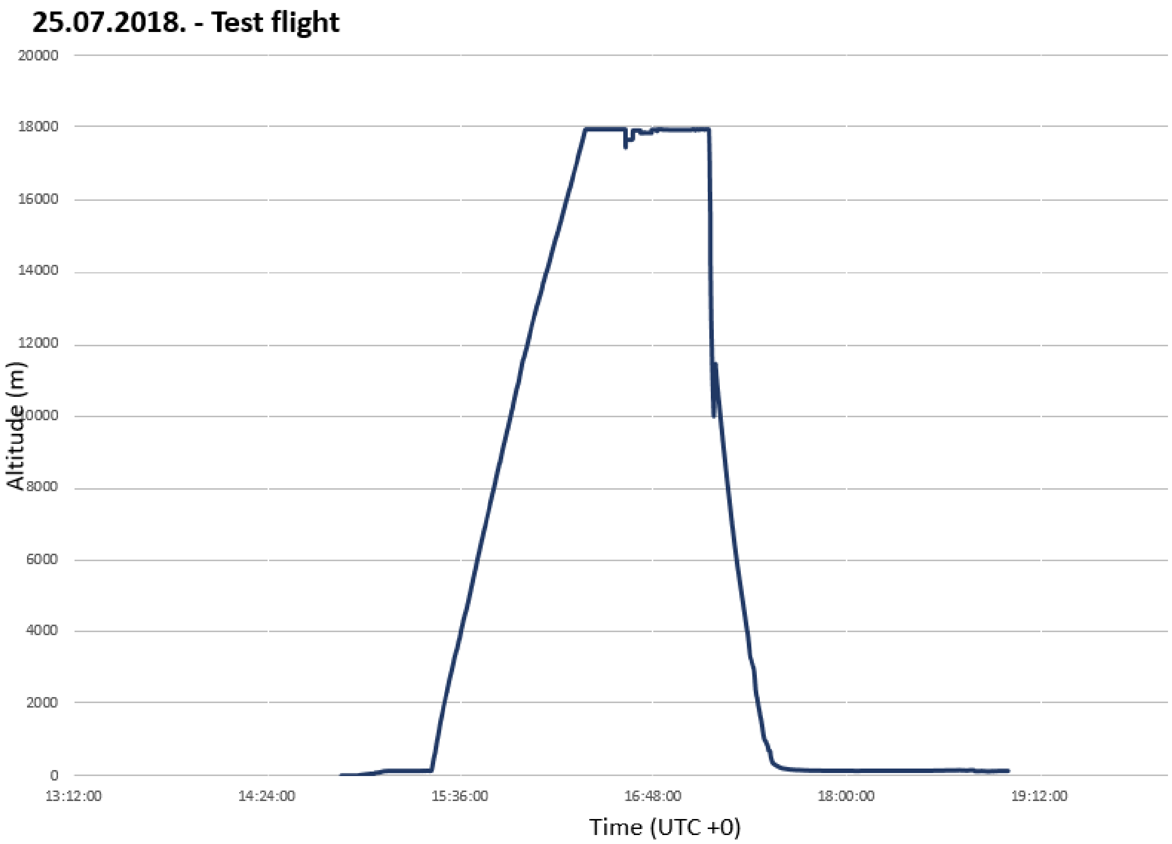

Fig. 4 – Altitude data collected in the third experiment. The plateau above 12 km is due to the GPS units crashing, reasons unknown

Summary and conclusions

This paper described the iterative process of the development of the so-called ‘Info-Droplets’ for modelling the dark flight phase of meteorite fall. Three successive steps of electronics and software development were carried out, each followed by flight tests to evaluate the capabilities. Each of the tests revealed important learnings for the further development of the Droplets. The fourth iteration of the instrument contains more sophisticated GPS instruments to allow high altitude measurements, radio communication between the droplets and the ground units, and improve antennae for communication. The software was also amended to allow the unique identification of each Droplet’s data, as well as restarting the instruments, should circumstances necessitate such measures.

Further experimentation will include a fourth, and hopefully final, test flight to validate the full capabilities of the Droplets. Experiments are also underway for the development of an appropriate housing to allow for free flight without destroying the instruments inside the casing. The results will be reported in subsequent papers.

Acknowledgements

The authors would like to thank the generous support, invaluable input and general co-operation by the personnel of Baja Observatory in general, and Dr. Tibor Hegedűs in particular, in the ongoing development of the Info-Droplets. Test flights were made possible by the Damball Team Baja Observatory. Authors are also grateful to Dr. Laszlo Bejo for his invaluable help in preparing this article.

Bibliography

Ceplecha, Z., 1961. Multiple fall of Přibram meteorites photographed. 1. Double-station photographs of the fireball and their relations to the found meteorites. *Bulletin of the Astronomical Inst.* of Czechoslovakia, vol. 12, p.21

Houston, TX, USA. Lunar and Planetary Institute. Paper: 1797, 2 p.

Jacchia, L.G., Whipple, F.L., 1956. *The Harvard photographic meteor programme.* Vistas in Astronomy 2:982-994. DOI: https://doi.org/10.1016/0083-6656(56)90021-6

Moilanen, J., Gritsevich, M., Lyytinen E., 2021. *Determination of strewn fields for meteorite falls.* Monthly Notices of the Royal Astronomical Society, 503(3):3337–3350, DOI: https://doi.org/10.1093/mnras/stab586

Towner, M. C., Jansen-Sturgeon, T., Cupak, M., Sansom, E.K., Devillepoix, H.A.R., Bland, P.A., Howie, R.M., Paxman, J.P., Benedix, G.K., Hartig, B.A.D., 2022. *Dark-flight Estimates of Meteorite Fall Positions:* Issues and a Case Study Using the Murrili Meteorite Fall. Planet. Sci. J. 3 44. DOI: https://doi.org/10.5065/D6M043C6

Vinnikov, V.V., Gritsevich, M.I., Turchak, L.I., 2016. *Mathematical model for estimation of meteoroid dark flight trajectory.* AIP Conference Proceedings 1773, 110016; DOI: https://doi.org/10.1063/1.4965020

Vizi, P.G., Berczi, S., Csizmadia, S., Hegedüs, T., 2016. *Extended Meteor Hunting with Smartphones as Surveillance Cameras.* In: 47th Lunar and Planetary Science Conference

Walla, E., 2018. Rapid detection and recovery—the science of hunting meteorites. DOI: https://phys.org/news/2018-02-rapid-recoverythe-science-meteorites.html