White Paper on “Global Space Heat Map” Project (Year 1)

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Summary

We provide a brief overview of the “Global Space Heat Map” Project in Year 1 (FY 2022-2023), including an overview of the implemented dashboard for visualizing space activities, as well as a section on identifying potential targets for grant applications in Year 2 (FY 2023-2024).

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Overview of the Space Heat Map Project

What is the state of pace activities? This is a simple question, but one that leads to a complex response. With advancements in technology and increased interest from both public and private sectors, the exploration and utilization of space are increasingly reaching new heights. Government space agencies, such as NASA and the ESA, continue to spearhead missions, including human space explorations, satellite launches, and robotic space missions, to explore the solar system and beyond, while private companies like SpaceX, Blue Origin, and Virgin Galactic have revolutionized the industry with reusable rockets (such as the Falcon 9) and ambitious plans for commercial space travel. The International Space Station remains a hub for scientific research and international collaboration, fostering breakthrough discoveries and advancements in various fields, and the newly launched James Webb Telescope is allowing us to see deeper than ever before into the universe. Moreover, the concept of space tourism is becoming a reality, with civilians venturing into space for leisure and adventure, and there is growing interest in space mining and extraction of resources from celestial bodies (e.g., asteroids). Such activities are also leading to their own problems, such as space debris and potential for future space conflicts (e.g., between nations) which require their own mitigation and response efforts. Despite this, as nations and corporations invest heavily in space-related activities, the future looks promising for further exploration, scientific discoveries, and commercial ventures beyond Earth's atmosphere.

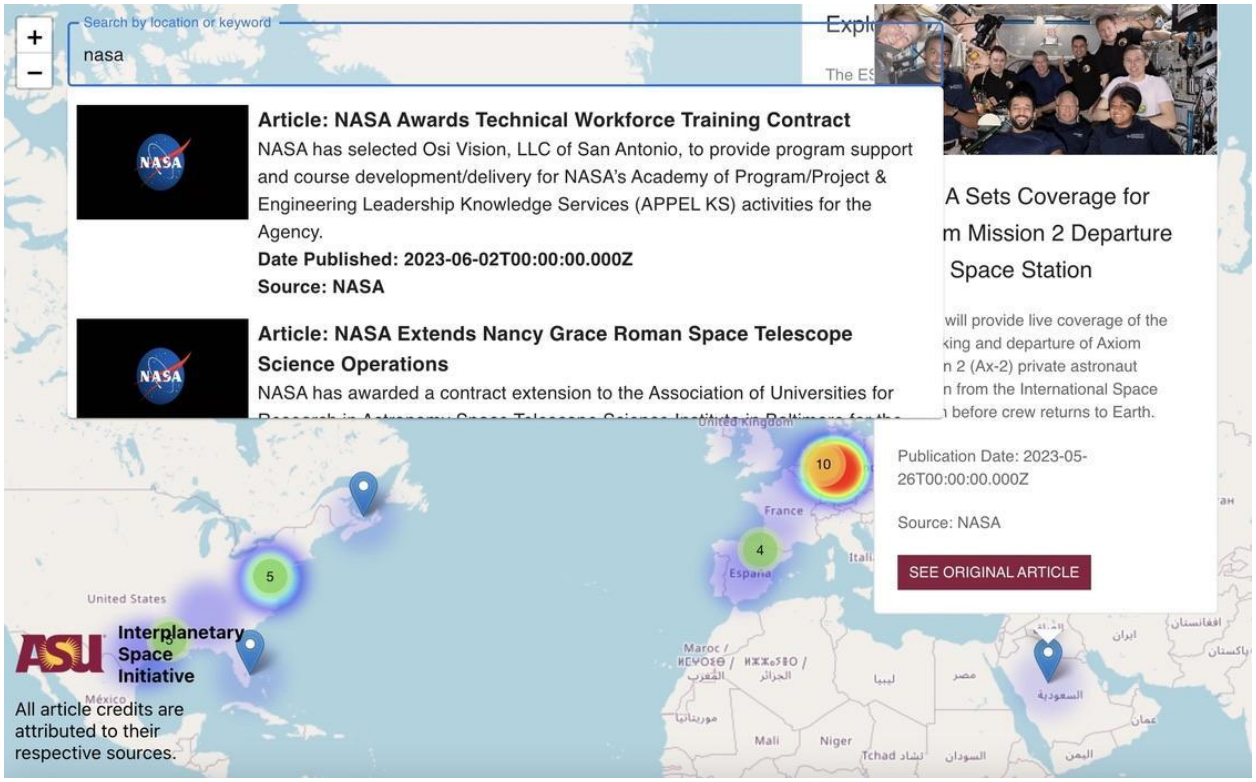
However, this brings us back to the original question, and the motivation for this project: *just what do space activities look like today? How can we characterize their extents? Their trends? Their foci?*

Succinctly, this project aims to develop a geographic “heat map” in a publicly accessible, online web dashboard that visualizes current space activities through the lens of their key benefits, drivers, and end goals, tracked at the project level over time, investment level, and geographic location. By visualizing space activities and how they are globally spread across our planet, the heat map represents:

1. An effective way of communicating the impact of space activities.

2. A visual, dynamic, and interactive framing of the benefits of space that will allow a broader set of stakeholders to engage with the information and take part in shaping future projects.

At a high level, in this project’s Year 1 (FY 2022-2023) we have implemented the initial system, composed of two primary components: (1) an initial web scraper that coordinates and updates (2) a heat map dashboard of space activities. This system is broken into four specific components (detailed in the next section), and represents a way to visually track and explore space activities that are happening around the world.



Technical Overview of the Space Heat map System

There are four core parts of the software system: the frontend dashboard, the API connecting the frontend to the backend, the backend, and a MySQL database hosted through AWS. These parts work in coordination to display the heat map system. However, the different blocks are not dependent on each other (i.e the backend scripts can be run independently to update the database which the frontend accesses through the API). There can also be a lack of functionality if one of the core blocks is not functioning properly (ex: the database server endpoint dying would result in no articles being shown on the map).

Frontend Dashboard

The frontend of the application is hosted on https://www.spaceheatmap.com/ as a React-based web page. The site queries the backend server (hosted on an Amazon ECS instance, see below) to retrieve articles based on the user's queries.

A search bar atop the page supports searching for articles. Currently, we support search via article titles, keywords, and locations. To the side of the search bar, a set of calendar widgets allows the user to restrict the start and end dates for which articles are selected. When queried, articles are retrieved from the database and loaded into the page on the heatmap. The map layer uses a Javascript library for interactive maps called Leaflet, and the overall frontend is

written using React (a open-source front-end JavaScript library for building user interfaces based on components). The following dependencies are used in the Node project:

```
"@emotion/react": "^11.11.0",
"@emotion/styled": "^11.11.0",
"@mui/icons-material": "^5.11.16",
"@mui/material": "^5.13.2",
"@mui/x-date-pickers": "^6.5.0",
"@mui/x-date-pickers-pro": "^5.0.20",
"@testing-library/jest-dom": "^5.16.5",
"@testing-library/react": "^13.4.0",
"@testing-library/user-event": "^13.5.0",
"axios": "^0.24.0",
"dayjs": "^1.11.7",
"leaflet": "^1.9.3",
"match-sorter": "^6.3.1",
"node-geocoder": "^4.2.0",
"react": "^17.0.2",
"react-dom": "^17.0.2",
"react-leaflet": "^3.0.0",
"react-leaflet-cluster": "^1.0.3",
"react-leaflet-heatmap-layer-v3": "^3.0.3-beta-1",
"react-scripts": "5.0.1",
"react-toastify": "^9.1.3",
"universal-geocoder": "^0.14.2",
"web-vitals": "^2.1.4"
```

API

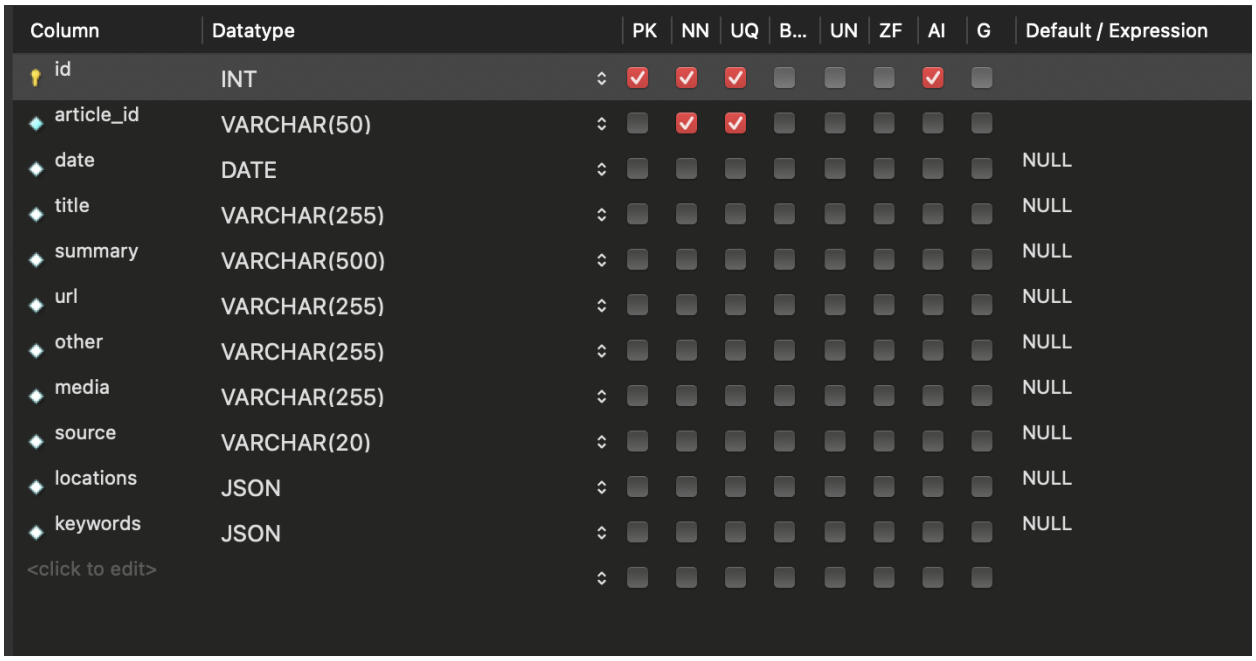
The API is set up as a separate Node project using different dependencies.

```
"cors": "^2.8.5",
"express": "^4.18.2",
"express-rate-limit": "^6.7.0",
"mysql": "^2.18.1",
"serverless-http": "^3.2.0"
```

When a search is executed from the frontend, a /fetch endpoint is called which performs a MySQL SELECT operation on the database via the mysql Python connector library. Likewise, once the results are retrieved, the API sends these back to the frontend for display in the updated page.

MySQL Database

The RDBMS (Relational Database Management System) used for this project was MySQL which was released in 1995 and is open-source. The choice was made due to MySQL's scalability, efficiency and the plentiful documentation available online related to this RDBMS. One table, article, was used for the moment to store article information with the following columns, datatypes, and primary key (PK in the screenshot):



Column	Datatype	PK	NN	UQ	B...	UN	ZF	AI	G	Default / Expression
id	INT	☑	☑	☑	☐	☐	☐	☑	☐	
article_id	VARCHAR(50)	☐	☑	☑	☐	☐	☐	☐	☐	
date	DATE	☐	☐	☐	☐	☐	☐	☐	☐	NULL
title	VARCHAR(255)	☐	☐	☐	☐	☐	☐	☐	☐	NULL
summary	VARCHAR(500)	☐	☐	☐	☐	☐	☐	☐	☐	NULL
url	VARCHAR(255)	☐	☐	☐	☐	☐	☐	☐	☐	NULL
other	VARCHAR(255)	☐	☐	☐	☐	☐	☐	☐	☐	NULL
media	VARCHAR(255)	☐	☐	☐	☐	☐	☐	☐	☐	NULL
source	VARCHAR(20)	☐	☐	☐	☐	☐	☐	☐	☐	NULL
locations	JSON	☐	☐	☐	☐	☐	☐	☐	☐	NULL
keywords	JSON	☐	☐	☐	☐	☐	☐	☐	☐	NULL
<click to edit>		☐	☐	☐	☐	☐	☐	☐	☐	

For Phase 2, one significant expansion to this database will be to add additional tables and indexes, to speed up the search process. Likewise, the API will be updated to take advantage of these - such as performing queries which execute faster.

Backend Scripts

The backend scripts are a set of Python files which crawl and access various space-related news sites, including Space.com, NASA, New Scientist, Cosmo BC, and ESA. These scripts extract information from articles, perform a set of analysis actions (e.g., extracting keywords, identifying a header image to represent the article in the dashboard, etc.), and then insert them into the MySQL database. The scripts utilize HTTP requests for fast data/article fetching. Moreover, the scripts check for duplicates before insertion into the database. The scripts are set up such that, as new sites are identified and scripts written for them, they can be integrated into the ensemble of existing scripts seamlessly. Currently, the scripts are hosted on the Amazon ECS instance, and set to automatically run according to a CRON job scheduler.

External Funding Opportunities

As a part of this project, the team has begun to investigate potential funding opportunities for external funding, both via federal and government agencies, and via private foundations and organizations. The intent in Year 2 is to develop one or more grant proposals that target these venues, and ask research questions that build upon the foundational activities in this project. Below, we list an initial set of candidate agencies and funding opportunities, which will be further expanded and investigated in FY 2024, leading to one or more grant applications.

NASA

NASA is the leading agency for space-related research, and funds research and technology development across a wide range of topics. Their omnibus solicitation is called the **Research Opportunities in Space and Earth Sciences (ROSES)**, and is composed of many different sub-calls for proposals, such as the Earth Science Research Program. NASA offers limited additional opportunities for funding, though there are a couple of candidates (e.g., Early Stage Innovations could be one) that will additionally be invetigated.

National Science Foundation

The National Science Foundation (NSF) is a federal agency that supports fundamental research and education in non-medical fields related to science and engineering. The NSF provides funding and grants to researchers, supports science education initiatives, and promotes scientific advancement across many disciplines and program areas. In contrast to NASA, the NSF does not publish an omnibus solicitation, but is instead composed of several directorates and program areas, each with their own solicitations and funding opportunities. Below, we detail a couple of potential targets, although more options will also be explored.

The **NSF's Directorate for STEM Education (EDU)** is interested in proposals to to develop a well-informed citizenry and a diverse and capable workforce of scientists, technicians, engineers, mathematicians and educators. EDU programs support STEM education at all educational levels and in a variety of settings. The directorate funds research and evaluation projects that seek to improve the accessibility, integration and adaptability in STEM education and beyond — ensuring that STEM education and career opportunities are accessible, inclusive and equitable for all Americans (including historically underrepresented demographics and communities).

Relevant funding opportunities in the EDU directorate include the Undergraduate Education program, which supports calls such as Pathways into the Earth, Ocean, Polar and Atmospheric & Geospace Sciences (GEOPAths), and Improving Undergraduate STEM Education: Directorate for STEM Education (IUSE), and the Division of Research on Learning in Formal and Informal Settings (DRL), which supports calls such as the Advancing Informal STEM Learning (AISL), Discovery Research PreK-12 (DRK-12), and Computer Science for All (CSforAll).

The **Division of Astronomical Sciences (AST)** (located in the Directorate for Mathematical and Physical Sciences) also provides several programs of interest. These include

the Astronomy and Astrophysics Research Grants (AAG), Cyberinfrastructure for Sustained Scientific Innovation (CSSI), and Education and Special Programs in the Astronomical Sciences (ESP).

Air Force Office of Scientific Research

Recently, the **Space University Research Initiative** (SURI) program was established by the Air Force Office of Scientific Research (AFOSR) and the Air Force Research Laboratory (AFRL) Chief Technologist Office and encourages participation between academia, the Air Force Research Laboratory (AFRL) space focused technology directorates, and industry. One of AFOSR's top priorities is to bolster Space Force basic research, and SURI is seen as one way to grow space-related research to meet U.S. Space Force's mission, strategy, and architectural challenges. More specifically, the program is intended to support basic and applied research in Space-related science and engineering at U.S. institutions of higher education with potential transition to essential applications of DOD interest. SURI supports multidisciplinary research efforts, ideally creating synergies to speed DoD-relevant research and development. SURI awards are intended to support high-risk, high-reward ideas.

Arizona New Economy Initiative

The Arizona New Economy Initiative is a state-based program in cooperation with ASU to improve and develop the Arizona workforce in sectors of interest, including advanced manufacturing and materials, advanced communication technologies, cybersecurity, artificial intelligence, automation and robotics, digital media, virtual and augmented reality, big data and more. The New Economy Initiative is supporting the development of five Science and Technology Centers, or STCs, at ASU, to nurture local industrial partnerships, research, workforce development, and educational programs.

Private Foundations and Organizations

In addition to federal programs, there are funding opportunities offered by private foundations and organizations. The below list includes organizations that fund research and educational efforts in either space or STEM:

- Universities Space Research Association
- The Planetary Society
- Simons Foundation
- Chan Zuckerberg Initiative
- Sloan Foundation