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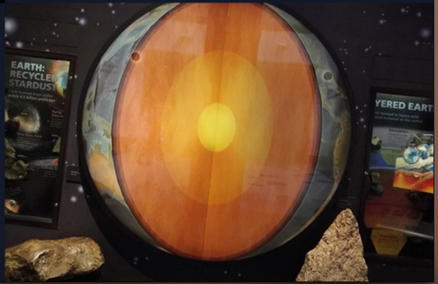
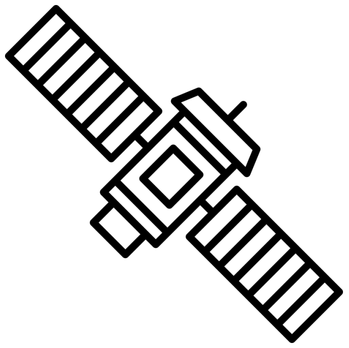
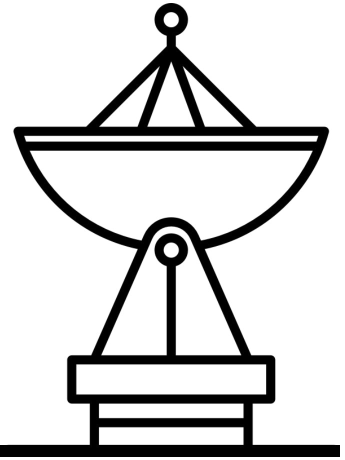


Space Debris

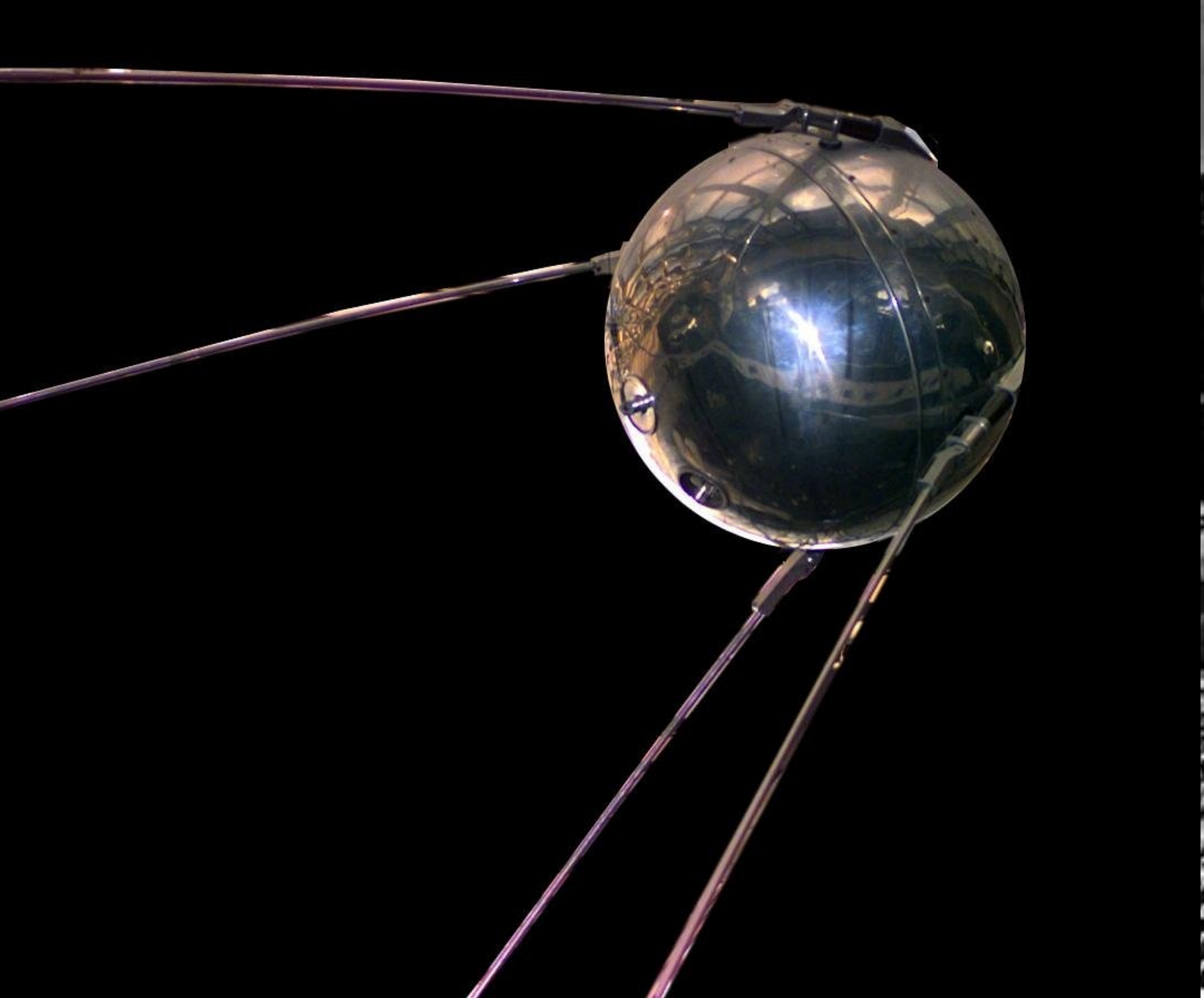
Questions Remain



- Where did it **come from**?
- Why can't we just **get rid of it**?
- What could **go wrong** if we don't?




Where did it
come from?




VOL. 83, NO. A6 JOURNAL OF GEOPHYSICAL RESEARCH JUNE 1, 1978

Collision Frequency of Artificial Satellites: The Creation of a Debris Belt

DONALD J. KESSLER AND BURTON G. COUR-PALAIS

NASA Johnson Space Center, Houston, Texas 77058

As the number of artificial satellites in earth orbit increases, the probability of collisions between satellites also increases. Satellite collisions would produce orbiting fragments, each of which would increase the probability of further collisions, leading to the growth of a belt of debris around the earth. This process parallels certain theories concerning the growth of the asteroid belt. The debris flux in such an earth-orbiting belt could exceed the natural meteoroid flux, affecting future spacecraft designs. A mathematical model was used to predict the rate at which such a belt might form. Under certain conditions the belt could begin to form within this century and could be a significant problem during the next century. The possibility that numerous unobserved fragments already exist from spacecraft explosions would decrease this time interval. However, early implementation of specialized launch constraints and operational procedures could significantly delay the formation of the belt.

INTRODUCTION

Since the beginning of the space age, thousands of satellites have been placed in earth orbit by various nations. These satellites may be grouped into three categories: payloads, rocket motors, and debris associated with the launch or breakup of a particular payload or rocket; most satellites fall into the last category. Because many of these satellites are in orbits which cross one another, there is a finite probability of collisions between them. Satellite collisions will produce a number of fragments, some of which may be capable of fragmenting another satellite upon collision, creating even more fragments. The result would be an exponential increase in the number of objects with time, creating a belt of debris around the earth.

This process of mutual collisions is thought to have been responsible for creating most of the asteroids from larger planetlike bodies. The time scale in which this process is taking place in the asteroid belt is of the order of billions of years. A much shorter time scale in earth orbit is suggested by the much smaller volume of space occupied by earth-orbiting satellites compared to the volume of space occupied by the asteroids.

Conceivably, a significant number of small satellite fragments already exist in earth orbit. Fragments which are undetected by radar are likely to have been produced from 'killer satellite' tests and the accidental explosions of rocket motors. Although some work has already been completed to estimate the number of these fragments, further investigations in this area are still required.

reached by this study that over the next few decades a significant amount of debris could be generated by collisions, affecting future spacecraft designs.

SATELLITE ENVIRONMENT MODEL

A model describing the environment resulting from orbiting satellites was constructed by first calculating the spatial density (average number of satellites per unit volume) as a function of distance from the earth and geocentric latitude. Flux (number of impacts per unit area per unit time) was then related to spatial density through the relative impact velocities. This technique was also used to model the collision frequency in the asteroid belt [*Kessler,* 1971].

Orbital perturbations can be expected to cause the orbital argument of perihelion and right ascension of ascending node to change fairly rapidly, causing these two distributions to be nearly random. This randomness was observed [*Brooks et al.,* 1975] and led to a uniform distribution in the spatial density as a function of geocentric longitude. The model was thus reduced to determining the spatial density S as a function of distance from the surface of the earth R and geocentric latitude β. To construct the model, volume elements were defined as ΔR = 50 km and $\Delta\beta$ = 3°. The spatial density in each of these volume elements was found by calculating the probability of finding each satellite in a particular volume element and then summing these probabilities. Spatial density is then this sum divided by the volume of the volume element.

The April 30, 1976, Satellite Situation Report [*NASA,* 1976]

END-OF-LIFE DISPOSAL OF GEOSTATIONARY SATELLITES

Rüdiger Jehn[1], **Vladimir Agapov**[2], **and Cristina Hernández**[1]

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[2]Keldysh Institute for Applied Mathematics, Moscow, Russia

ABSTRACT

For more than 25 years, the practice of reorbiting of a geostationary satellite at the end of its mission in order to protect the GEO environment has been recommended and performed by a number of operators. In recent years, an internationally recognised re-orbiting altitude has been defined by the Inter-Agency Space Debris Coordination Committee (IADC). Based on orbital data contained in the DISCOS database, the situation on the geostationary ring is analysed. In January 2005, from 1124 known objects passing through the geostationary region, 346 are controlled within their allocated longitude slots, 416 are drifting above, below or through GEO, and 143 are in a libration orbit. For 153 objects there is no orbital information available and for 60 uncatalogued objects orbital elements are derived from European measurements. In the eight years from 1997 to 2004, 117 spacecraft reached their end of life; 39 were reorbited in compliance with the IADC recommendation, 41 were reorbited below the minimum recommended altitude, and 37 were abandoned without any end-of-life disposal manoeuvre. Apart from these catalogued objects, the ESA 1-m telescope has observed many smaller debris (down to 10-15 cm) in this orbital region representing a collision risk for GEO spacecraft which is difficult to quantify.

1. INTRODUCTION

The geostationary ring is a valuable resource currently

for end-of-mission disposal were issued by national and international institutions as described by Johnson (1999) and in a United Nations Committee for the Peaceful Use of Outer Space report (1999). In 1995 the International Academy of Astronautics (IAA, 1995) recommended to reorbit "geostationary satellites at end-of-life to disposal orbits with a minimum altitude increase 300-400 km above GEO depending on spacecraft characteristics". At the same time, space agencies like NASA, JAXA, Roskosmos and ESA developed national guidelines. All recommended an altitude increase of more than 200 km above GEO. Finally in 1997, an international consensus was found within the Inter-Agency Space Debris Coordination Committee (IADC, 1997). The recommended minimum altitude increase (in km) is given as

$$\Delta H = 235 + 1000 \cdot C_R \cdot A/m \qquad (1)$$

where C_R is the solar radiation pressure coefficient (usually with a value between 1 and 2), A is the average cross-sectional area and m is the mass of the satellite.

In view of these guidelines and recommendations one would expect that the geostationary ring is a well protected and unlittered space. However only about one third of all satellites follow the internationally agreed recommendations. Two out of three satellites are reboosted into an orbit so low above GEO that they will sooner or later interfere with geostationary satellites or they are com-

Image: Getty

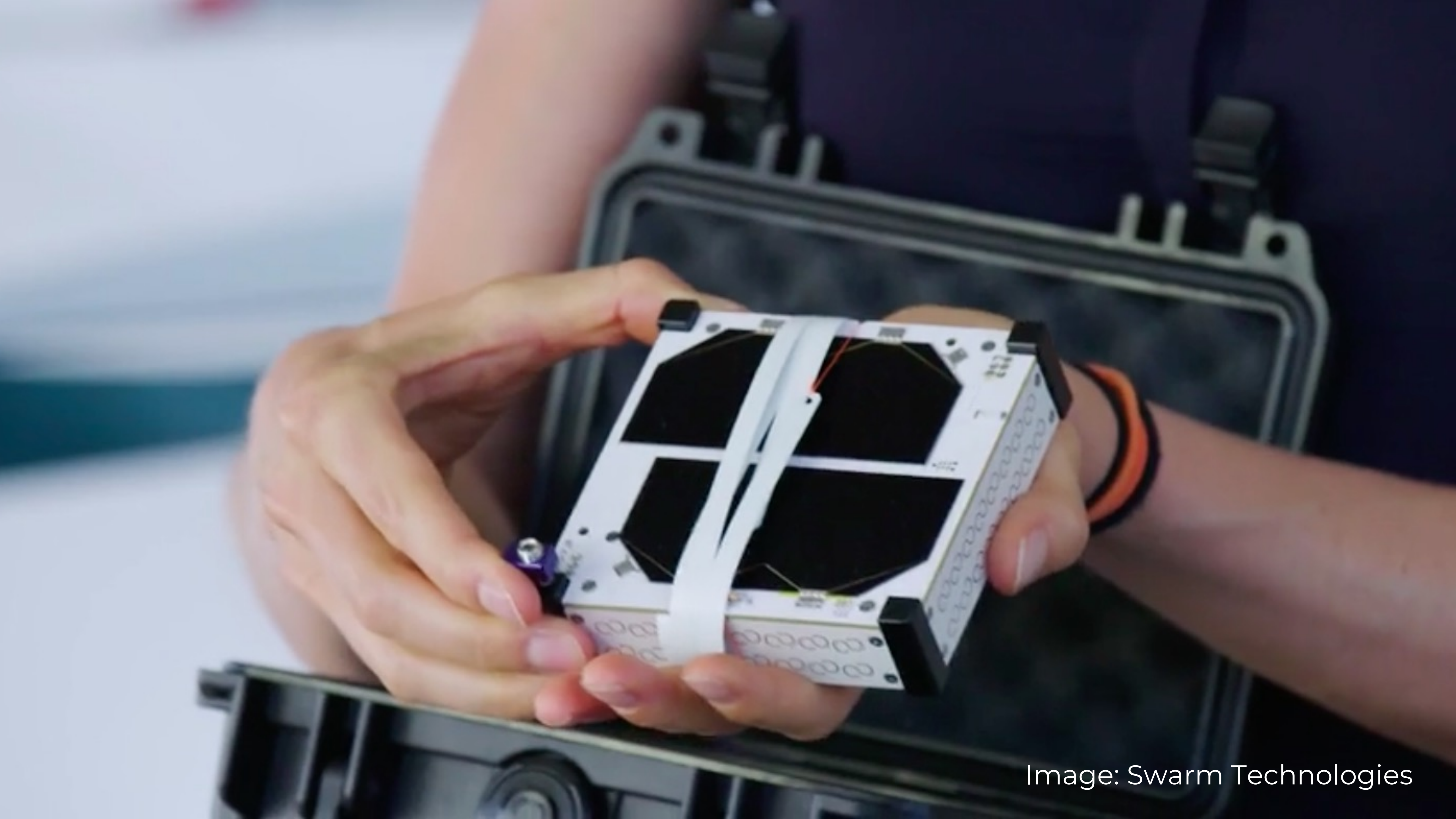

Image: Swarm Technologies

Elon Musk's 42,000 StarLink Satellites Could Just Save The World

John Koetsier Senior Contributor
John Koetsier is a journalist, analyst, author, and speaker.

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Jan 9, 2020, 11:49am EST

Elon Musk's *other* company, SpaceX, is building Starlink, a global communications constellation that could approach a staggering 42,000 satellites. And it could be all that stands between us and a fragmented world living in virtually — and actually — different realities.


Persistent and
wilful inaction
for decades


No
Admittance

Why can’t we just get rid of it?

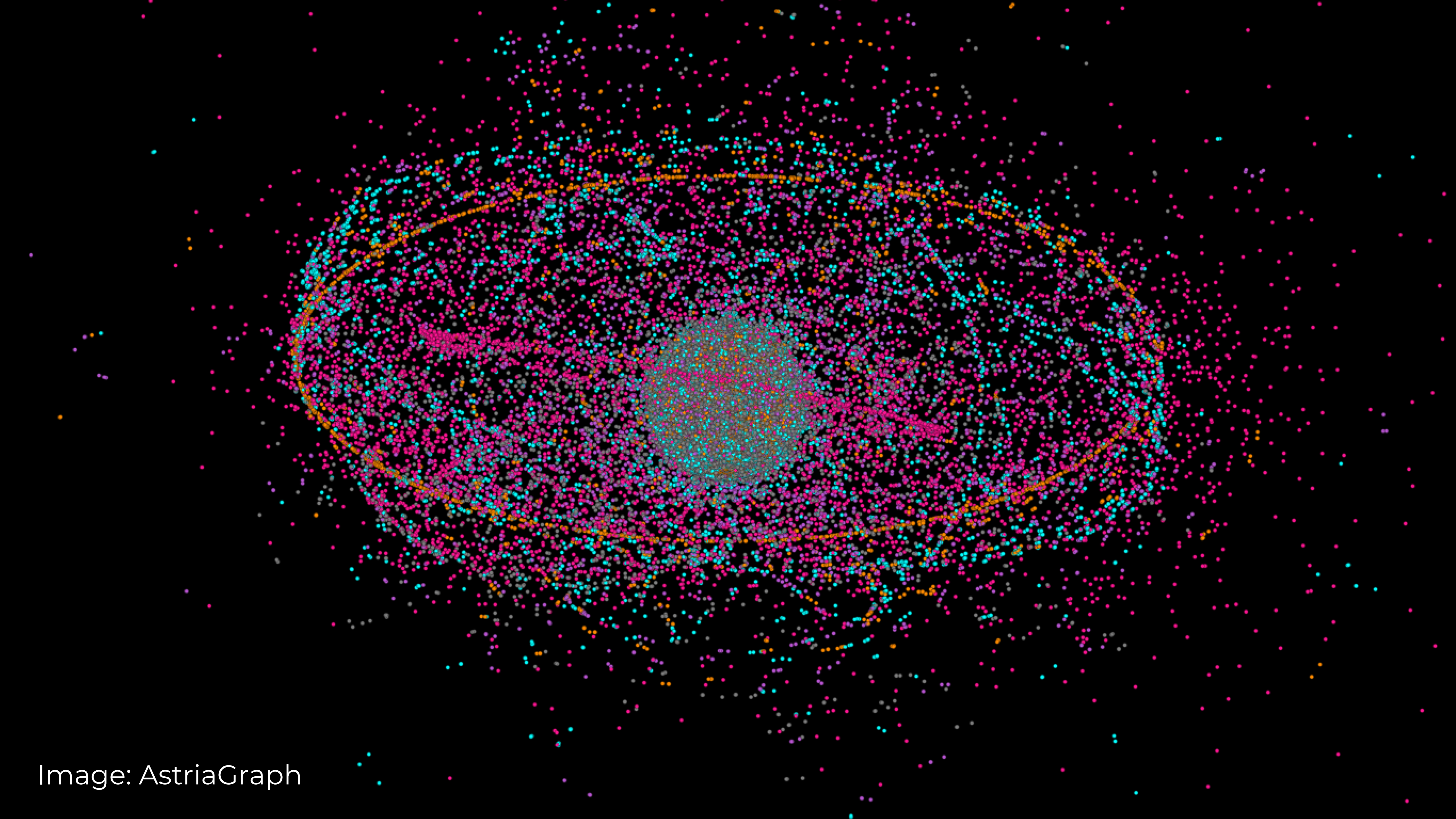
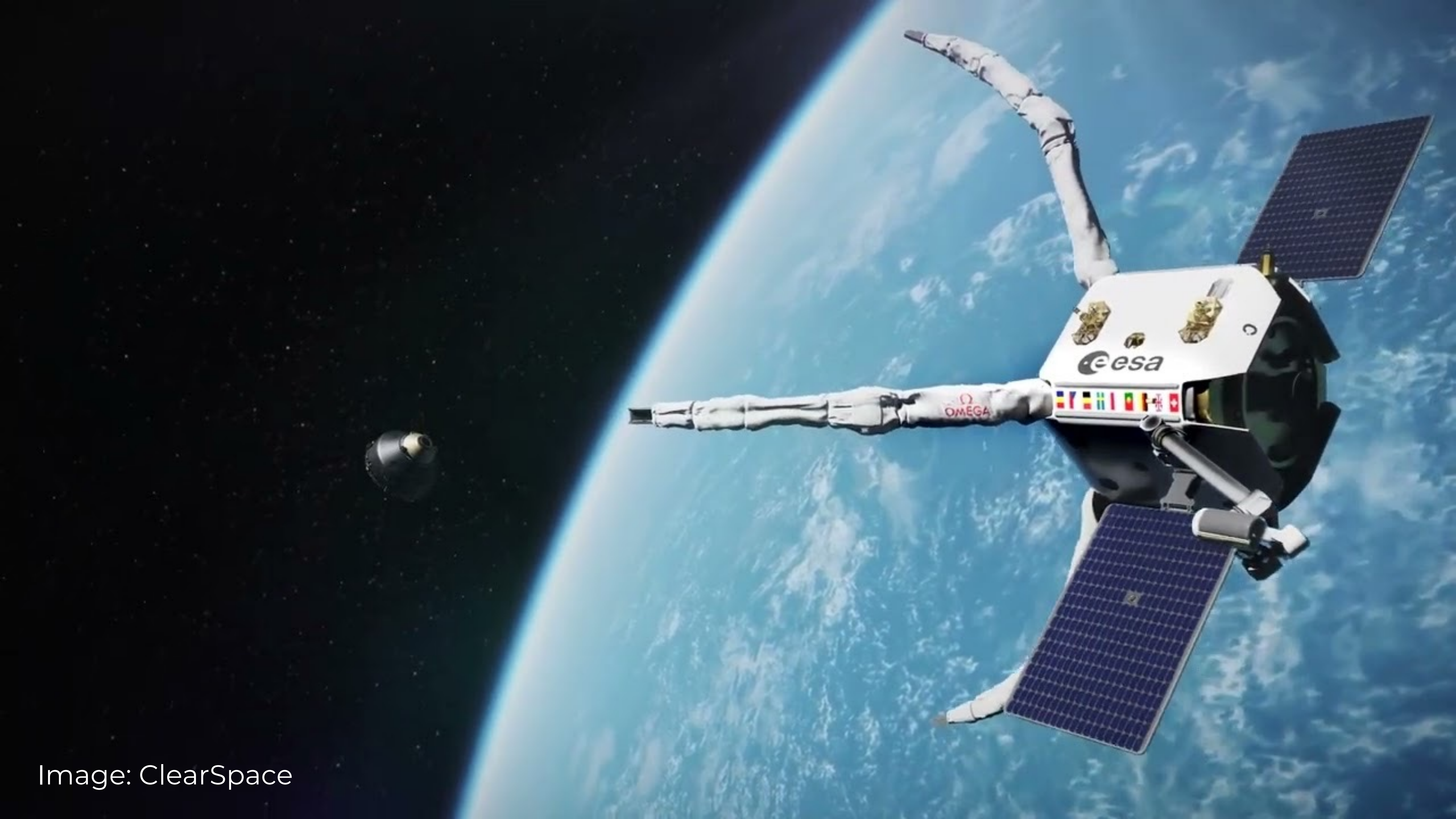


Image: AstriaGraph



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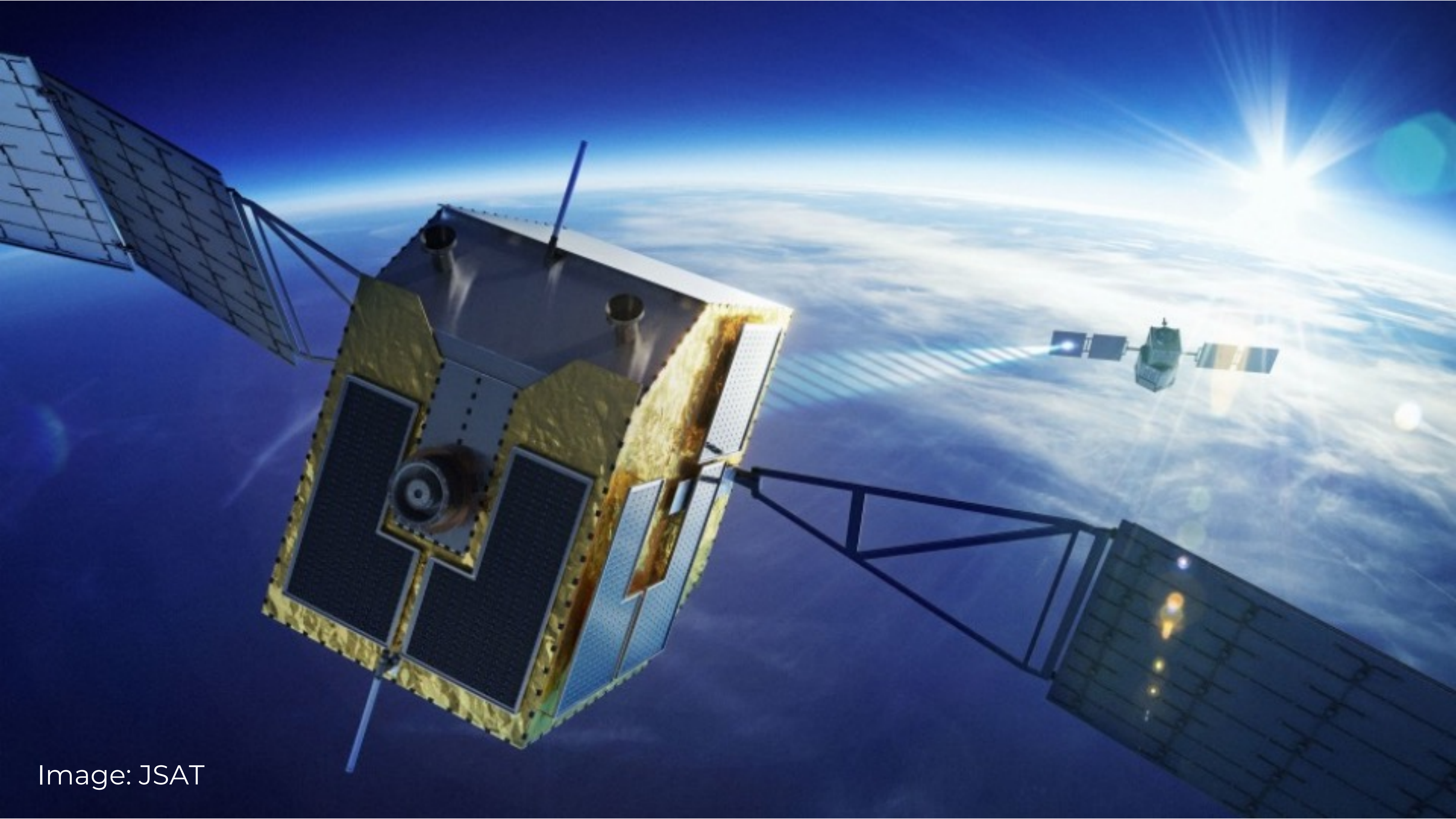

Image: JSAT

Image: The Mercury


We still need
space traffic
management

Image: Brand Tasmania


Image: UTAS

What could go wrong if we don't?


NO STANDING
AUSTRALIA
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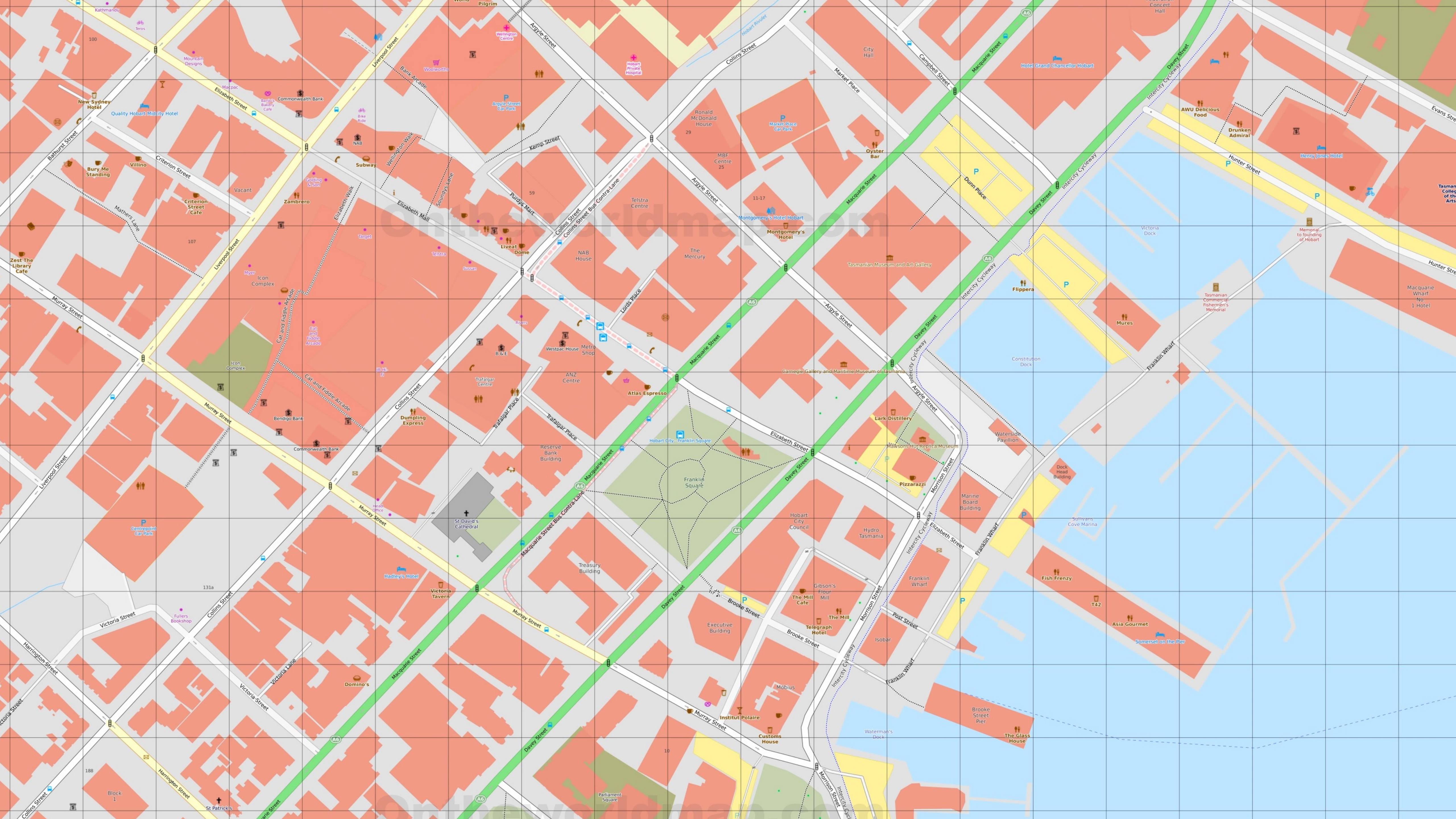
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Subway
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MBF Centre
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Criterion Street
Vacant
Golding & Son
Zambrero
Criterion Street Cafe
Mathers Lane
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Elizabeth Walk
Elizabeth Mall
Soundys Lane
Purdys Mart
59
Collins Street Bus Contra-Lane
Telstra Centre
11-17
Montgomery's Hotel Hobart
Montgomery's Hotel
Victoria Dock
Memorial to founding of Hobart
Zest The Library Cafe
Liverpool Street
Myer
Target
Telstra
Icon Complex
Liveat
Dome
Sussan
NAB House
The Mercury
Lords Place
Tasmanian Museum and Art Gallery
Flippera
Macquarie Wharf No 1 Hotel
Tasmanian Commercial Fishermen's Memorial
Murray Street
Cat and Fiddle Arcade
Rivers
Westpac House
Metro Shop
B & E
Mures
Constitution Dock
Franklin Wharf
Icon Complex
JB Hi-Fi
Trafalgar Centre
ANZ Centre
Carnegie Gallery and Maritime Museum of Tasmania
Atlas Espresso
Lark Distillery
Bendigo Bank
Dumpling Express
Trafalgar Place
Hobart City - Franklin Square
Mawsons Hut Replica Museum
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U-BOAT


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to our way
of life

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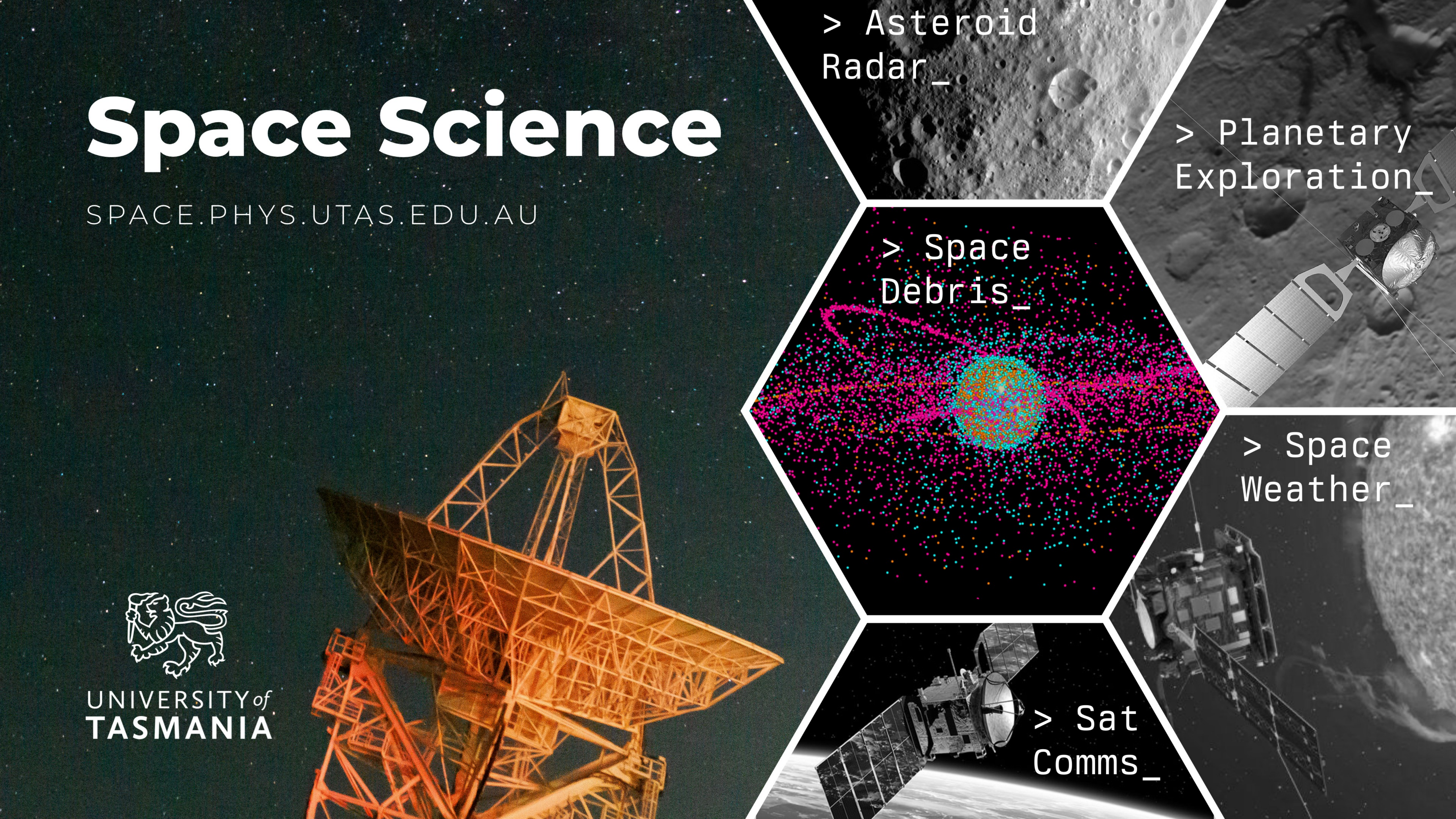
Image: Brand Tasmania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