The Pan-STARRS Search for Near-Earth Objects

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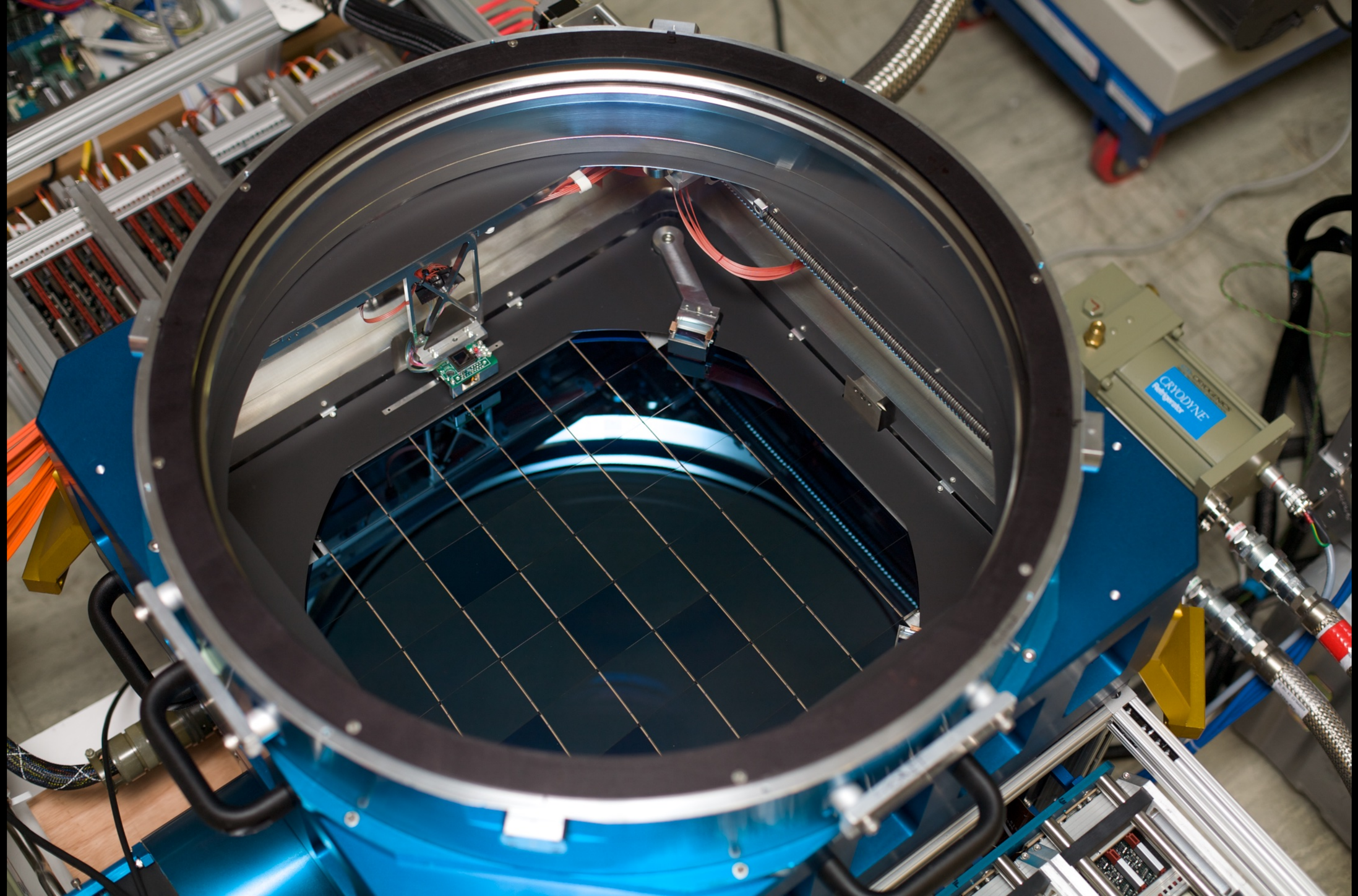
The Pan-STARRS Telescopes

- Pan-STARRS consists of two 1.8-meter diameter telescopes located near the summit of Haleakala, on the Island of Maui, in Hawaii
- They are wide-field telescopes, each with a field-of-view 3 degrees in diameter, covering an area of 7 square degrees
- Each telescope has a camera at the Cassegrain focus, and a large secondary mirror 0.9 meter in diameter
- Both Pan-STARRS Telescopes survey the sky searching for Near-Earth Objects
- This search is funded by NASA’s Near-Earth Object Observations program

The Pan-STARRS Cameras

- Each Pan-STARRS Telescope has a very large camera
  - PS1 has a 1.4 Gigapixel camera
  - PS2 has a 1.5 Gigapixel camera
- These are still the largest cameras in the world, but will be surpassed by the camera for the Rubin Observatory once it becomes operational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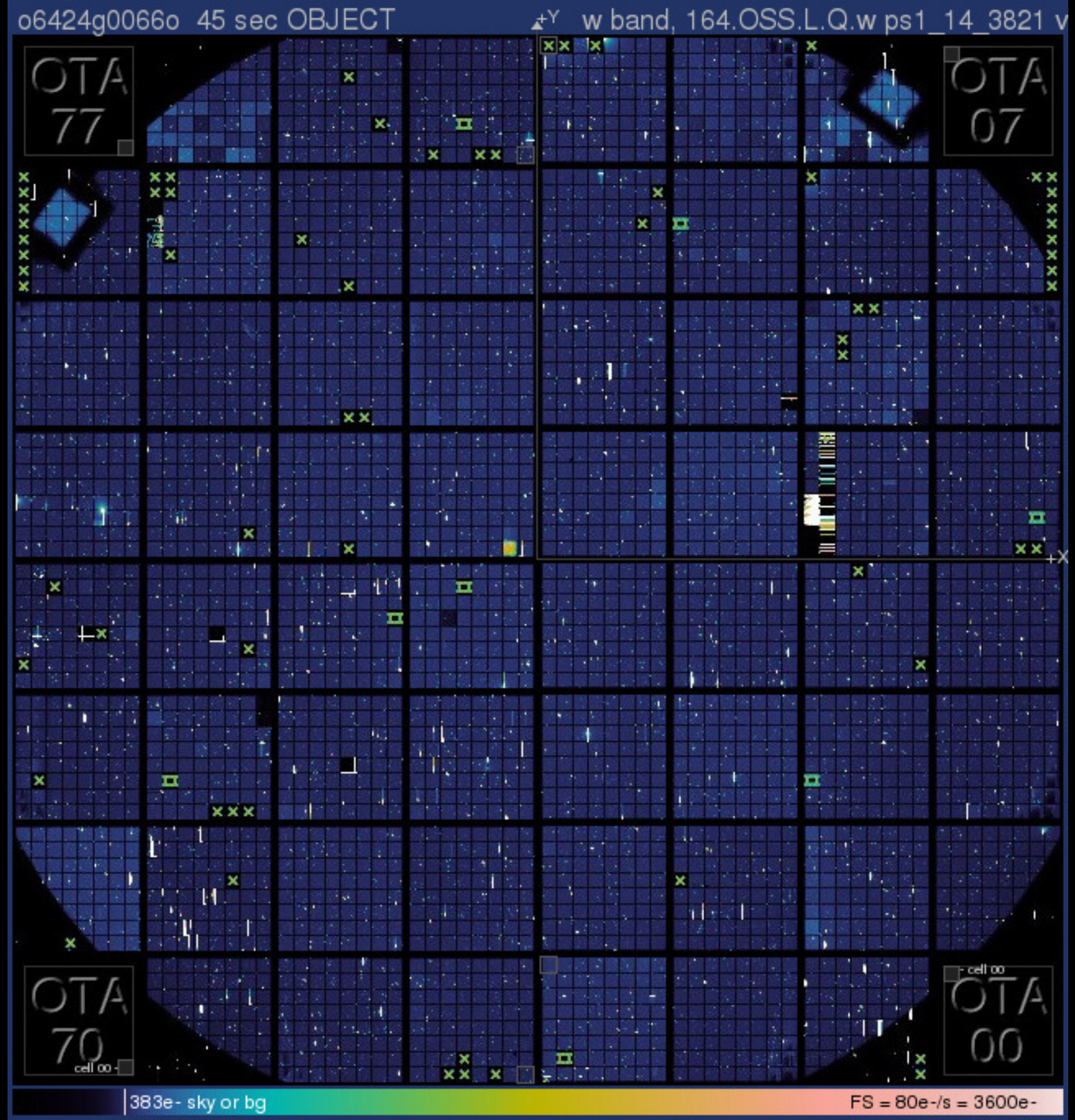
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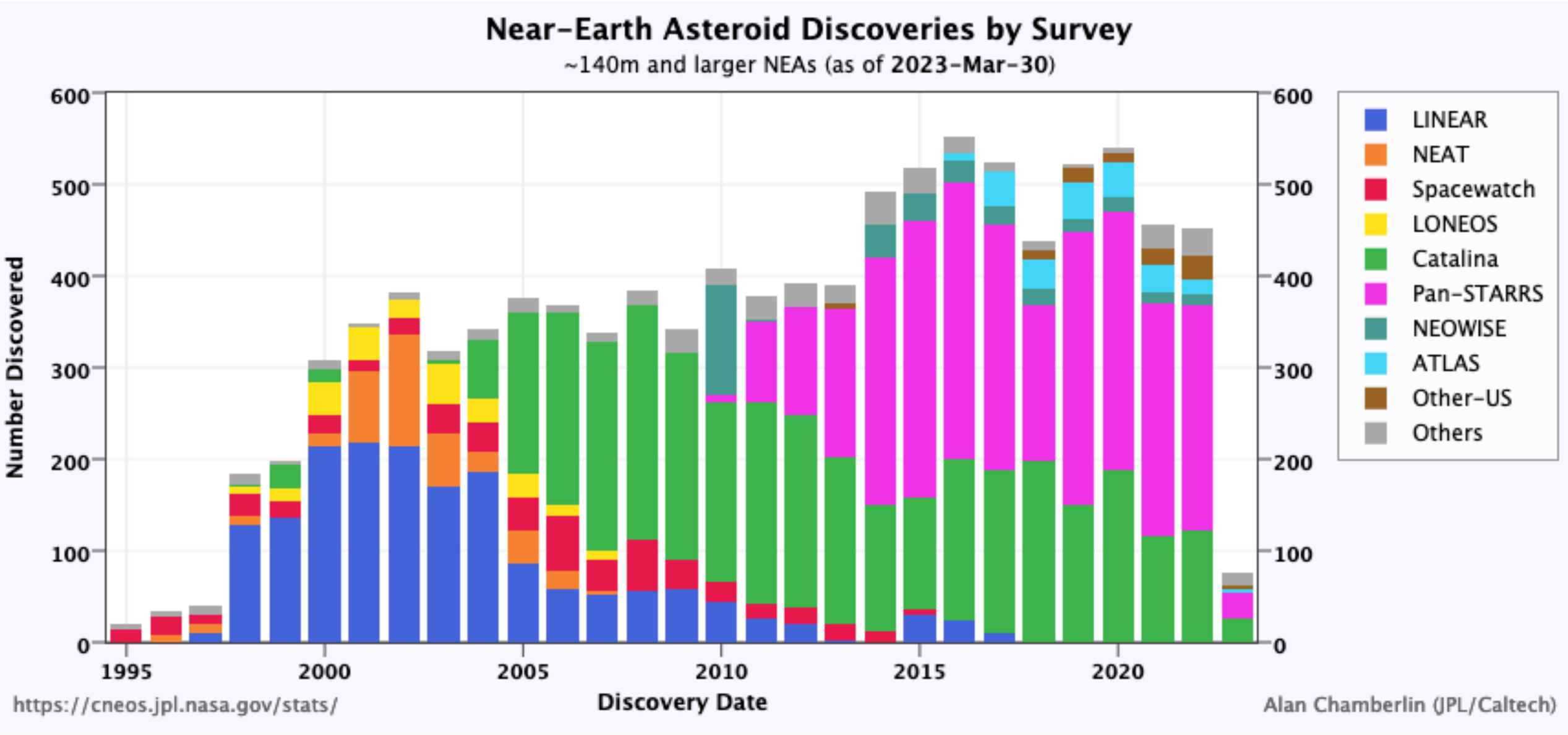
The Pan-STARRS Survey

- Congress has tasked NASA with finding 90% of all objects with diameter > 140 meters
  - As of now, only approximately 41% of these have been found
    - When Pan-STARRS started in 2011, only 18% had been found
- One of the major strength of Pan-STARRS is finding these larger objects
  - Pan-STARRS is the leading survey for discovery of larger NEOs, discovering 54% of the total discovered in the last 3 years


Near-Earth Asteroid Discoveries by Survey
~140m and larger NEAs (as of 2023-Mar-30)
Number Discovered
Discovery Date
0
100
200
300
400
500
600
1995
2000
2005
2010
2015
2020
LINEAR
NEAT
Spacewatch
LONEOS
Catalina
Pan-STARRS
NEOWISE
ATLAS
Other-US
Others
https://cneos.jpl.nasa.gov/stats/
Alan Chamberlin (JPL/Caltech)

The Pan-STARRS Survey

- Pan-STARRS1 started surveying the sky in late 2010
- Pan-STARRS2 started surveying the sky in 2018, and after a slow start, PS2 now discovers a similar number of Near-Earth Objects to PS1
- A sequence of four images spaced over an hour is used to find moving objects (usually asteroids)
    - Near-Earth objects usually have unusual motion due to Earth proximity
- The most important discovery to date by Pan-STARRS is the first interstellar object, `Oumuamua, discovered in October 2017

Severe Weather and Pan-STARRS

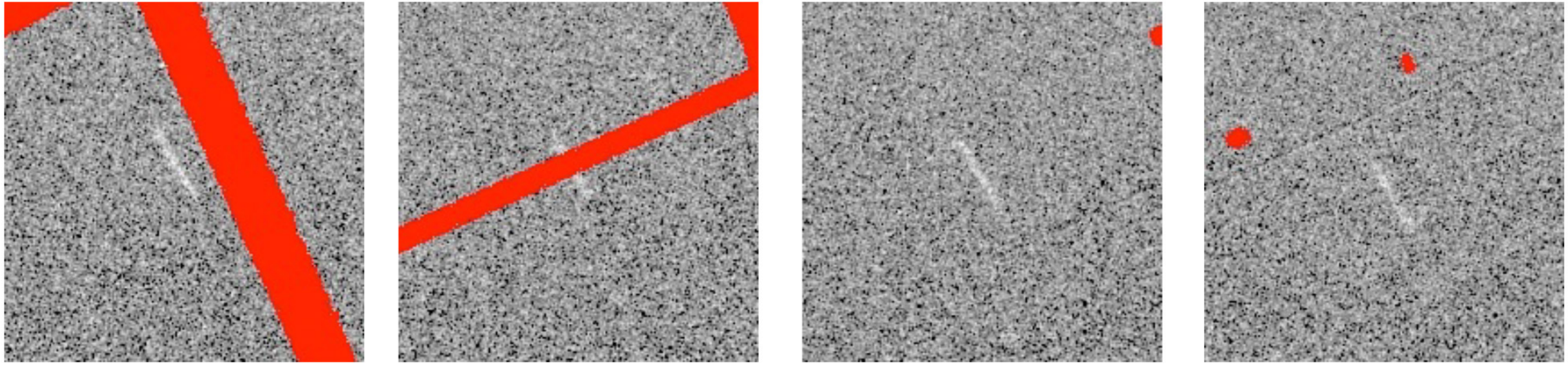
- Haleakala has seen an increasing amount of severe weather in the last few years
  - Power is delivered to the summit of Haleakala using overhead lines. These lines traverse Haleakala National Park and a habitat for endangered birds
  - Each winter for the last 3 years, an ice storm has brought down the lines
    - Repair is slow because permits are needed and the work must be supervised by a biologist

Severe Weather and Pan-STARRS

- Data are transferred from the summit of Haleakala via a fiber, that is buried in a conduit
  - In 2022, very heavy rain caused erosion in a gully, cutting the conduit and the fiber
    - Repair was slow, and only a temporary fix is in place at present
  - The data rate from Pan-STARRS is too high to be transferred by radio links
- A severe thunderstorm in early 2023 resulted in a lightning strike to the utility power system
  - All telescopes on Haleakala suffered damage

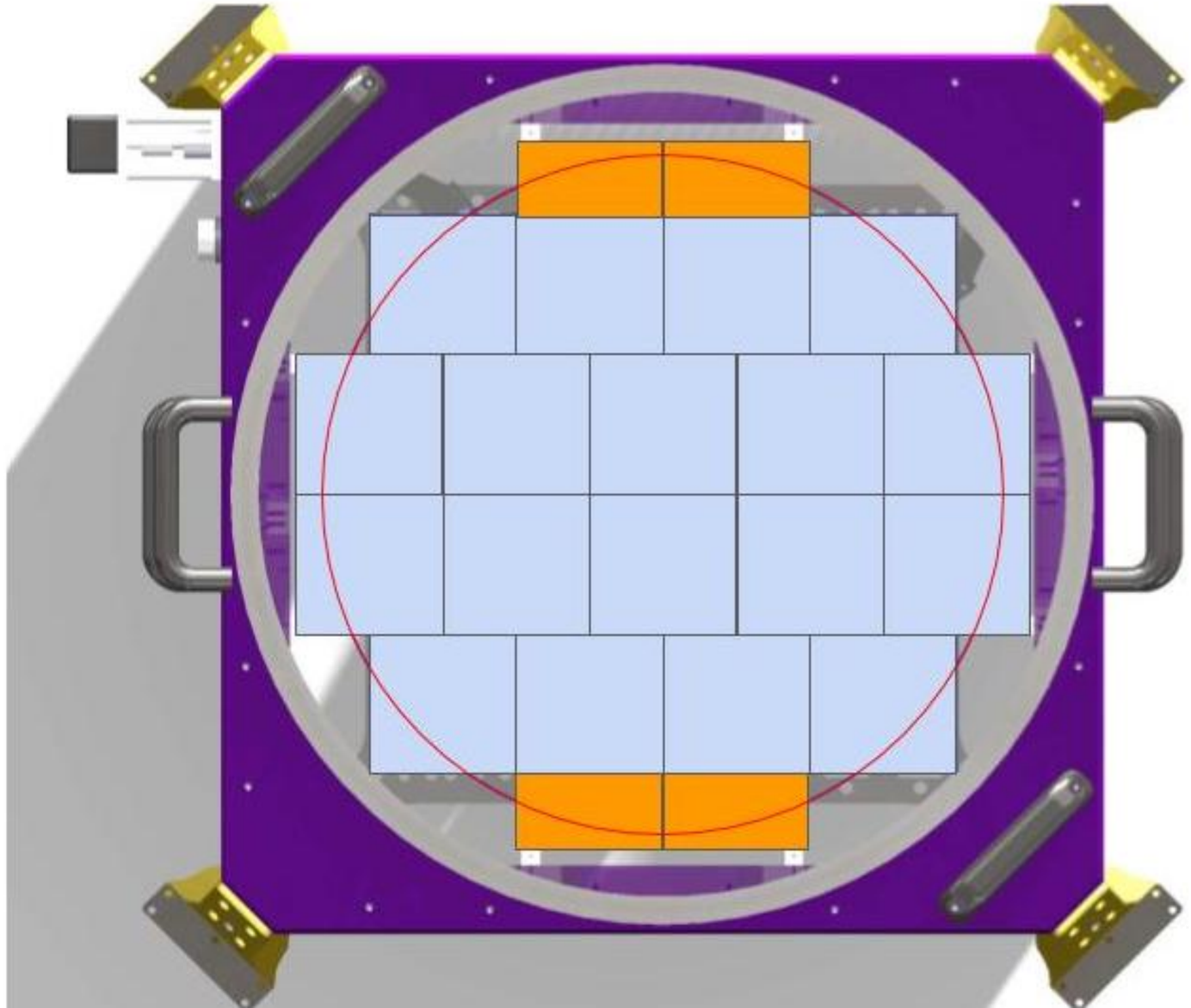
The Pan-STARRS cameras can be improved

- The Orthogonal Transfer Array structure, with 800x800 cells is harmful for discovery of moving objects; they also have poor cosmetics and non-Gaussian noise
- Cell boundaries corrupt detections
- At least three detections from four observations are required



Layout of a Proposed New Camera

- 18 9k x 9k CCDs
- 4 smaller CCDs
  - Each with 10μm pixels
- Total of 1.7 Gigapixels



Summary of Improvements

- Fill factor — improved from 70% to 90% — a factor 1.3
- Increasing the imaged area — a factor 1.1
- Reducing overhead by faster readout — a factor 1.1
- Increasing quantum efficiency of the detectors — a factor 1.1
- Together, these yield a factor 1.8 improvement, which does not take into account the improvement in the noise characteristics, which means that a raw improvement in survey power by approximately a factor 2 is possible

Impact on Near-Earth Object discovery

- A new camera on Pan-STARRS would produce a large increase in the discovery rate of fast moving Near-Earth Objects by Pan-STARRS
    - These would include other interstellar objects, which are probably already being seen by Pan-STARRS, but not reported and discovered
- The discovery rate of larger Near-Earth Objects would be improved
- The discovery rate of small Earth-impacting objects would also be improved
- The new camera would enable longer, deeper exposures
- Observations by Pan-STARRS in the north would better complement the observations from the Rubin Observatory in the south