meteorite collection on the lunar surface

darick baker, luke erikson, william rance, erik spahr
angel abbud-madrid, michael heeley
colorado school of mines
college of william and mary

photo credit: NASA image exchange

the story so far...

- 4 physics PhD students from Colorado School of Mines and the College of William and Mary
- competed in the 2007 lunar ventures business plan competition
- resolved: aggressive meteorite detection and collection on earth and the moon would produce scientific and financial rewards

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“the gift that keeps on giving”

- the words of Dr. Squyres regarding samples taken from outside the earth’s atmosphere
- many current missions directly measure the composition of foreign bodies (Cassini-Huygens, Deep Impact, Hayabusa, Stardust)
- as our presence in space increases so will the relevance of these samples

retrieval missions are expensive

mission	approximate cost	size
apollo	$135,000,000,000	382kg
mars direct	$20,000,000,000	5kg
genesis	$264,000,000	<1g
stardust	$200,000,000	<1g
hayabusa	$170,000,000	<1g

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samples must be important!

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how about delivery?

- ~10 million sizable meteorites have hit earth during the last 250 years
- only ~3000 have been found
- most of these have been found by farmers
- meteorites have already been found to originate from mars
- many more impacts occur on the moon

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meteorites are samples

- huge scientific interest (almost 14,000 published scientific articles)
- huge collector interest (a number of meteorite markets already exist)
- this is the only way to receive some samples
- the lunar surface is a treasure trove and may be the best place for meteorite collection in the entire solar system

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scientific interest

Dr. Squyres (principal scientist on mars rover missions) discussing the importance of retrieving off-world samples

Dr. Russell holds a tiny fragment of a martian meteorite

This recently found meteorite suggests new meteorite types await discovery.

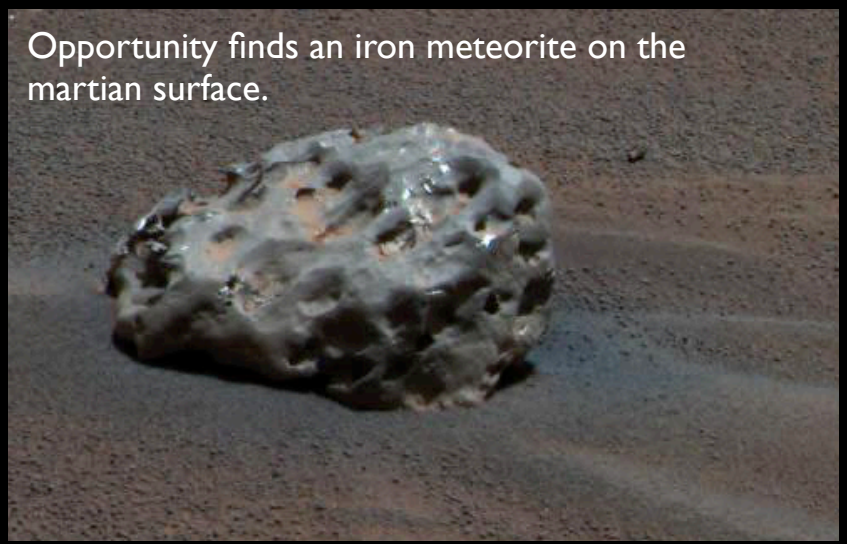
Opportunity finds an iron meteorite on the martian surface.

photo credits: BBC/NASA Image Exchange

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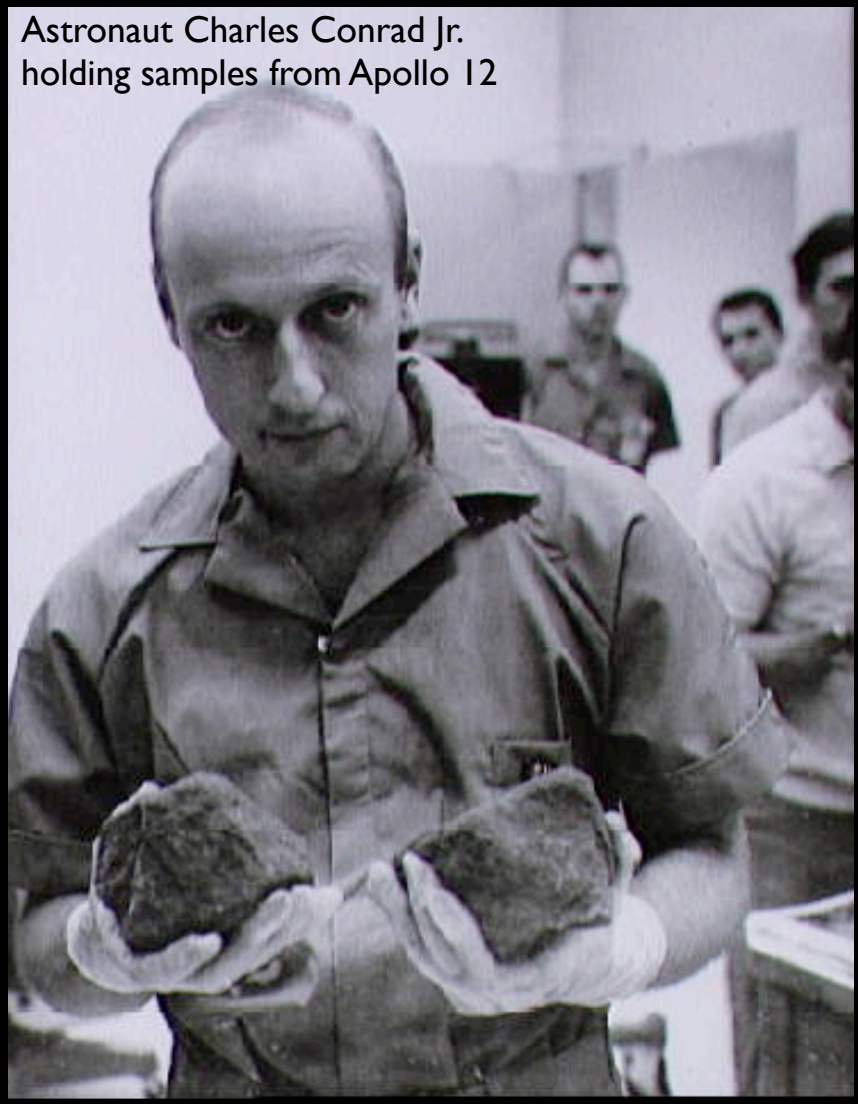
lunar projections

- NASA payed ~$350,000/gram for Apollo's samples -- and no meteorites were found!
- efficient collection of samples from the moon will reduce more costly retrieval missions elsewhere
- space agencies will want to exploit the meteorite resources of the moon because it is cost/time/effort efficient



Astronaut Charles Conrad Jr. holding samples from Apollo 12

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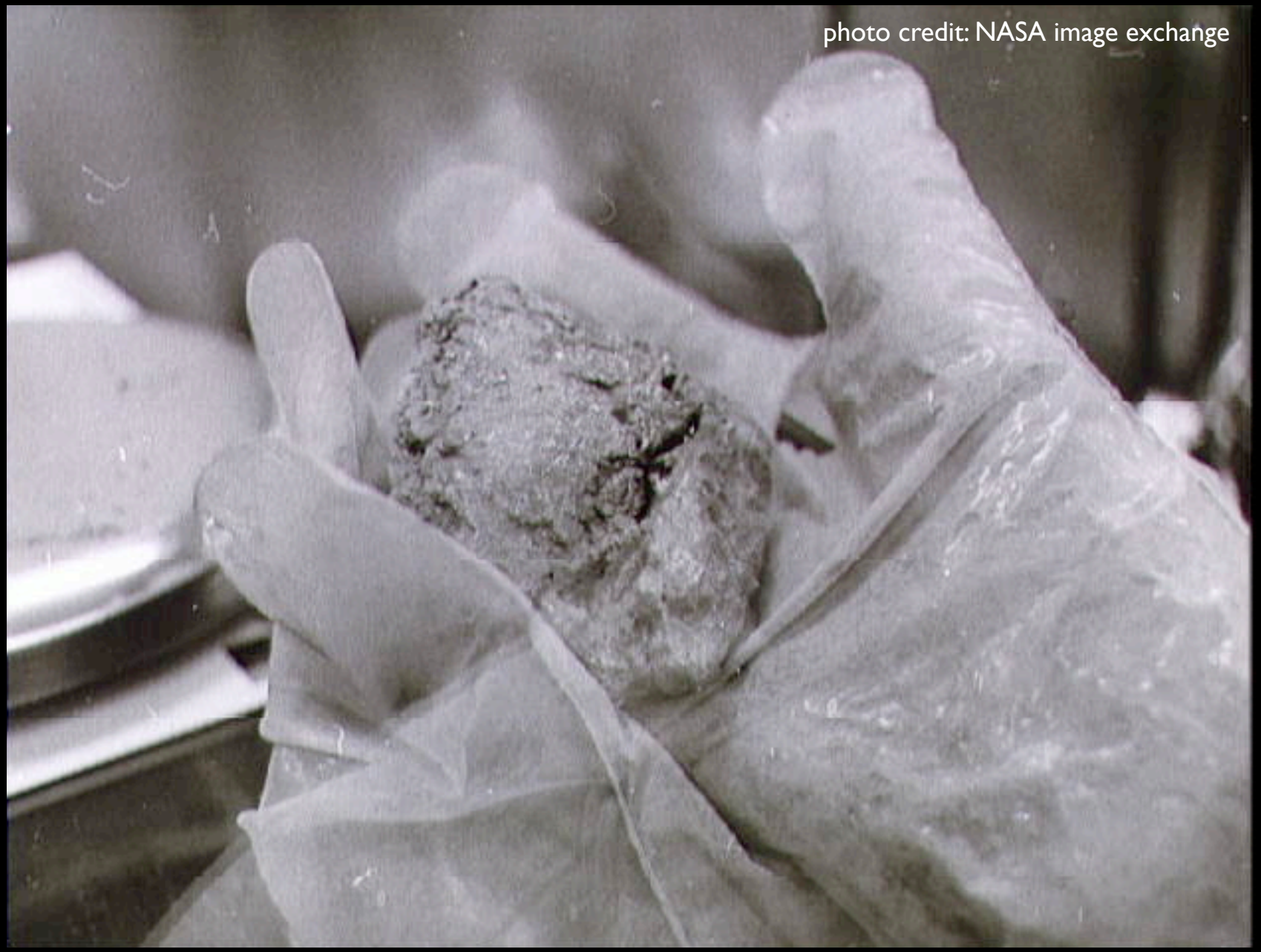

A scientist's gloved hand holds one of the numerous rock samples brought back to Earth from the Apollo 12 lunar landing mission. This sample is a highly shattered basaltic rock with a thin black-glass coating on five of its six sides. Glass fills fractures and cements the rock together. The rock appears to have been shattered and thrown out by a meteorite impact explosion and coated with molten rock material before the rock fell to the surface.

state of the art?

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state of the art?

recovery on the moon calls for a better approach

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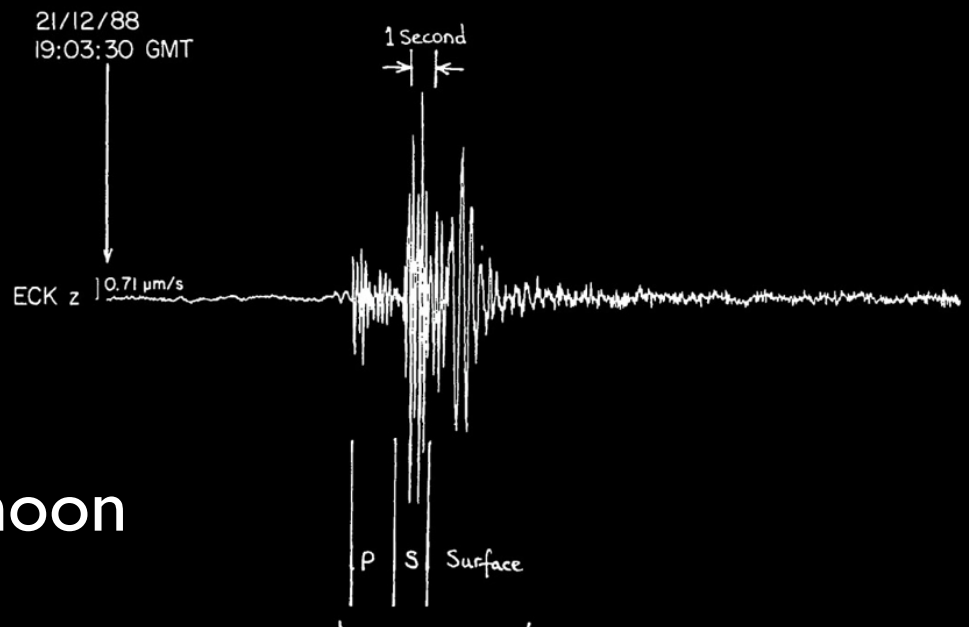
more retrieval with better technology

- seismic, ultrasound, satellite, visual, magnetic sensors are well established technologies
- plus all have detected meteorite impacts
- the cost of these technologies have decreased dramatically in the last 20 years (USGS seismic waveforms are free!)
- many tools and techniques developed on earth would work even better on the moon



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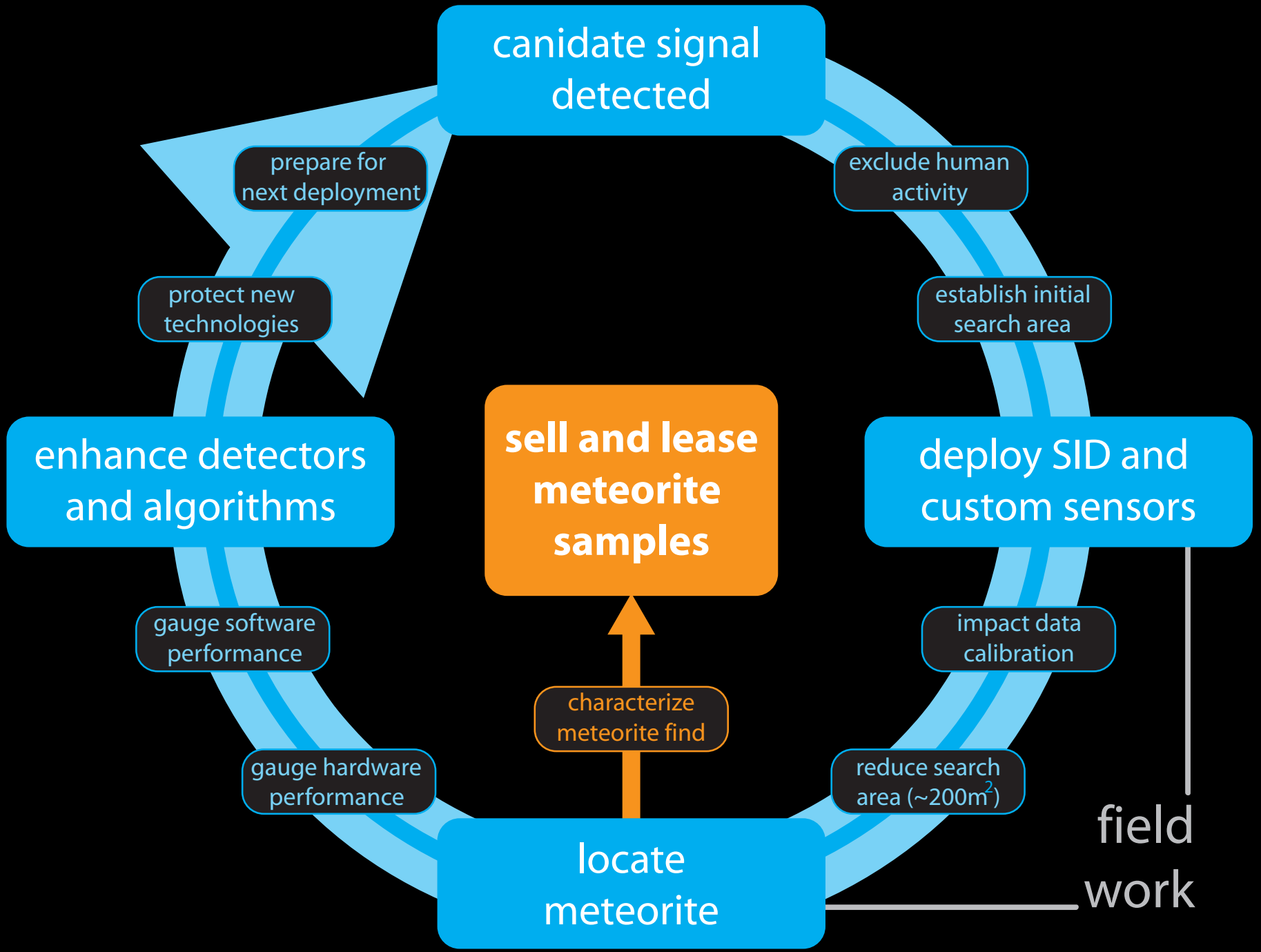

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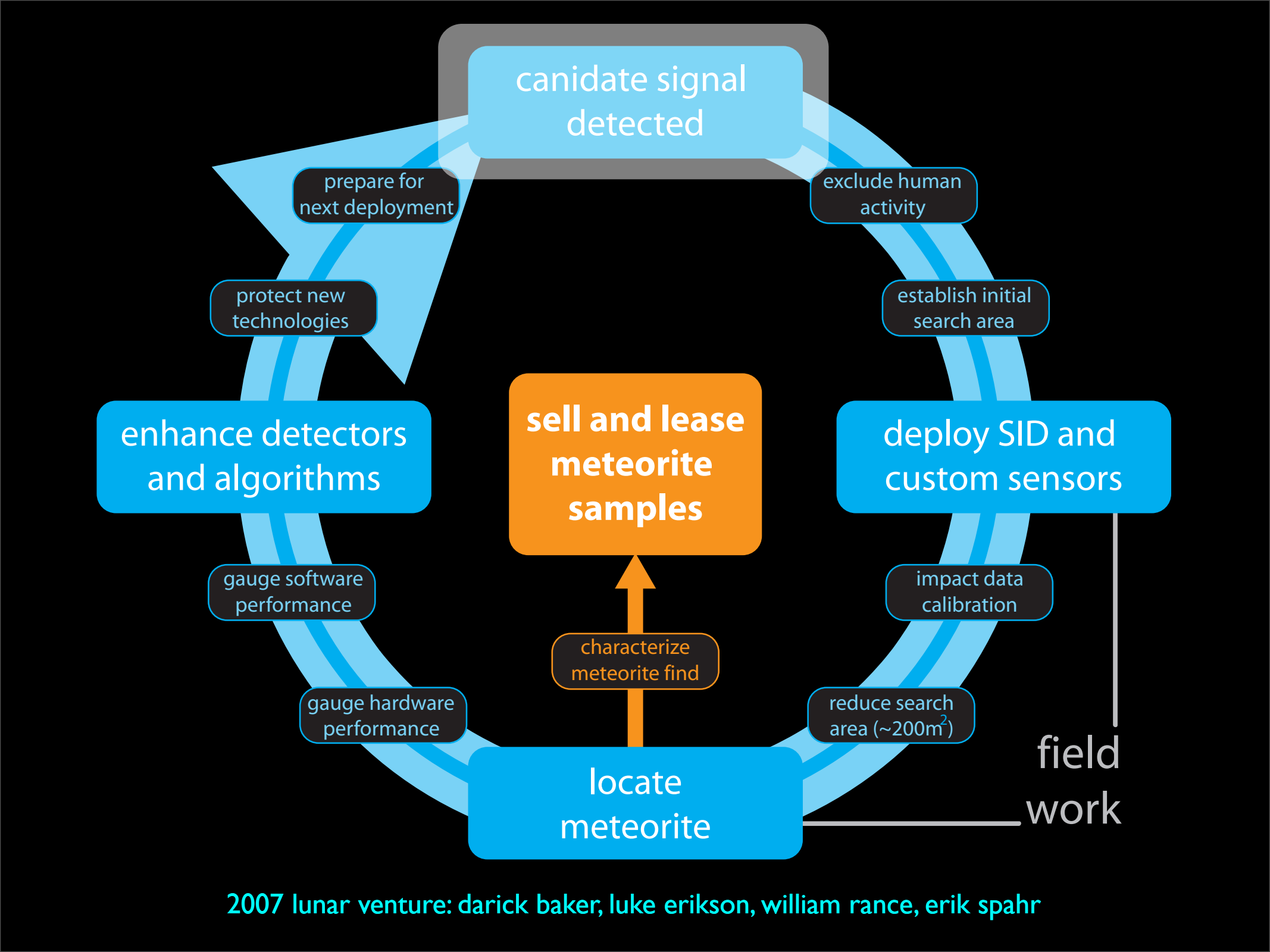

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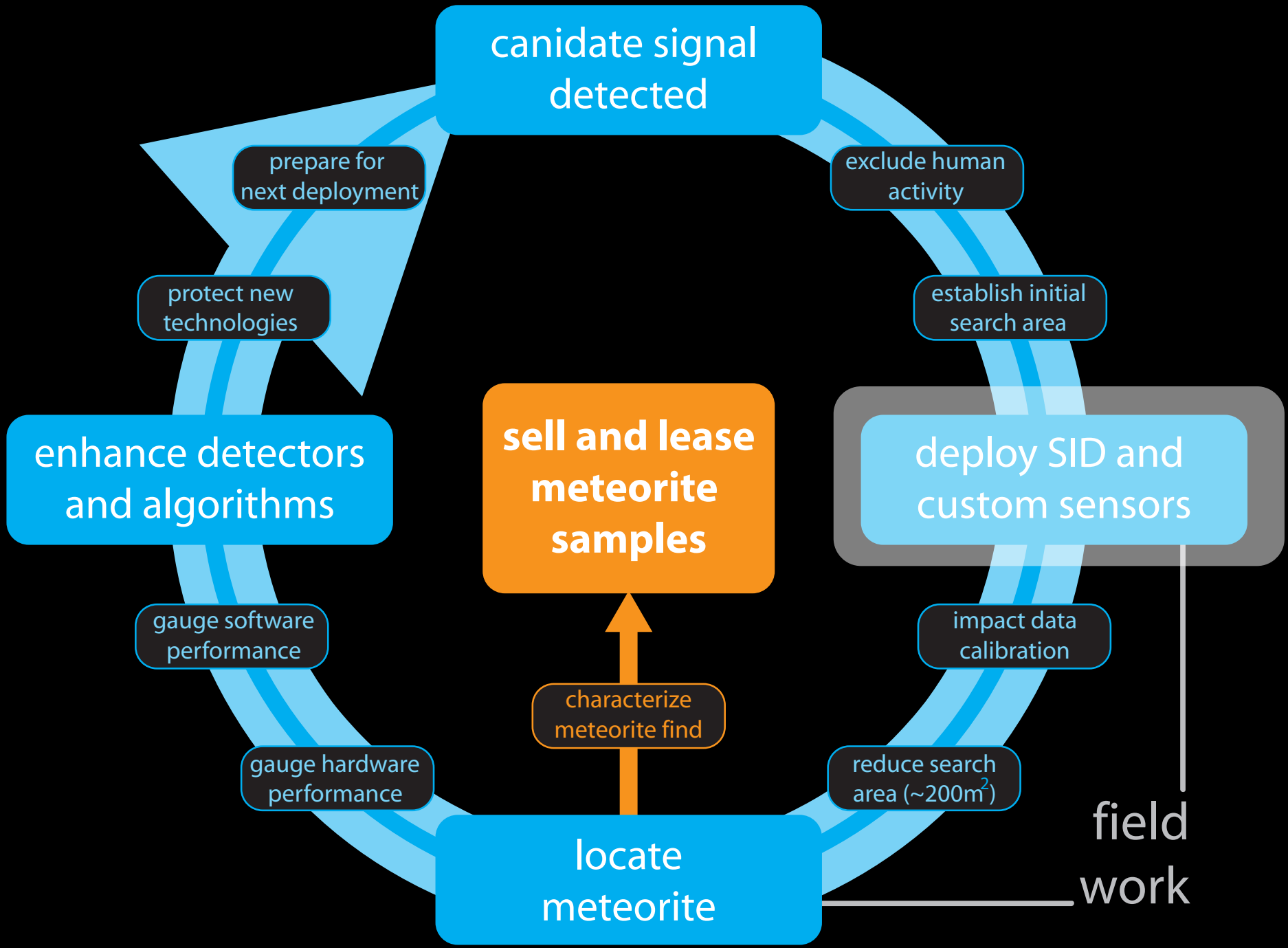

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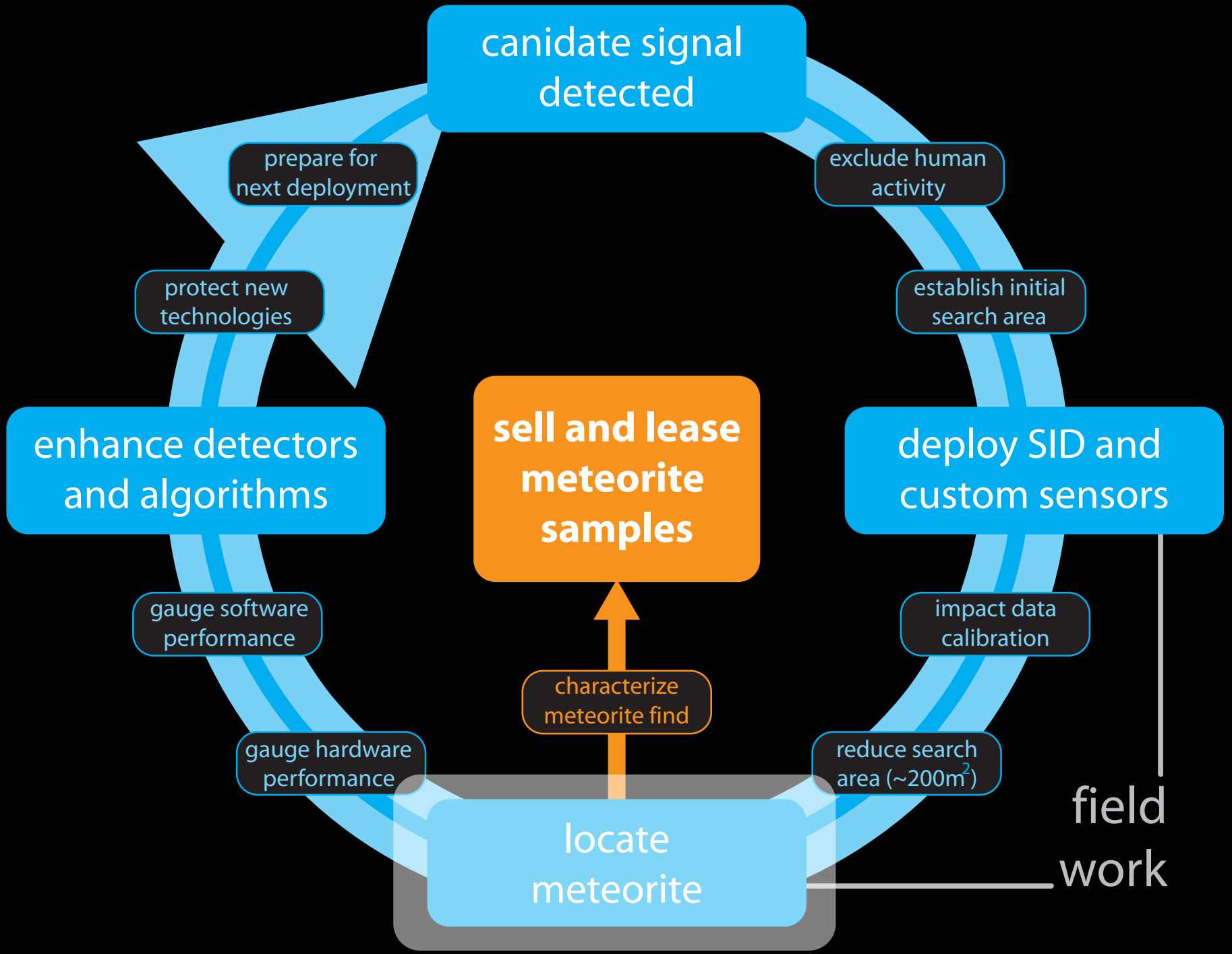

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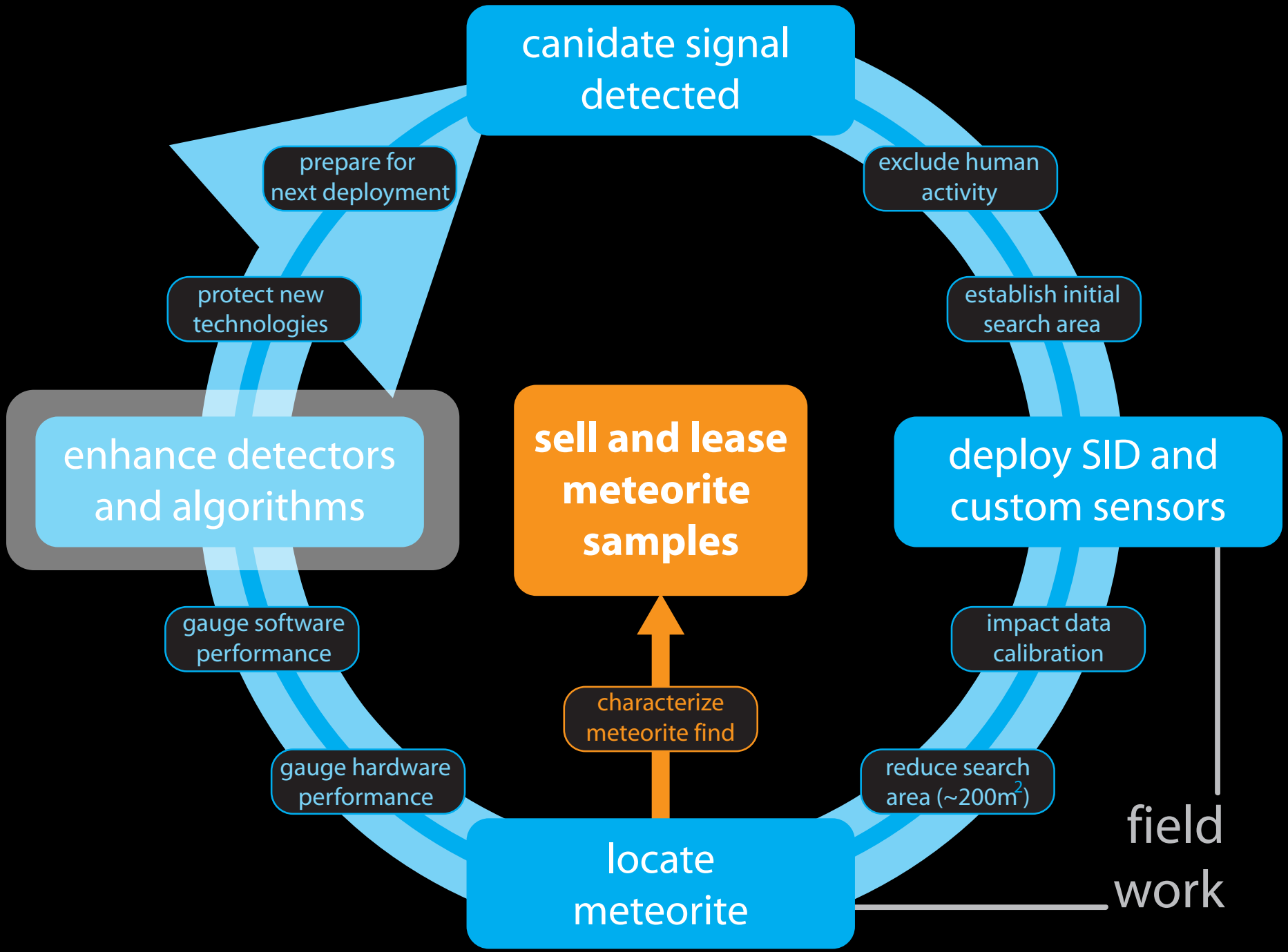

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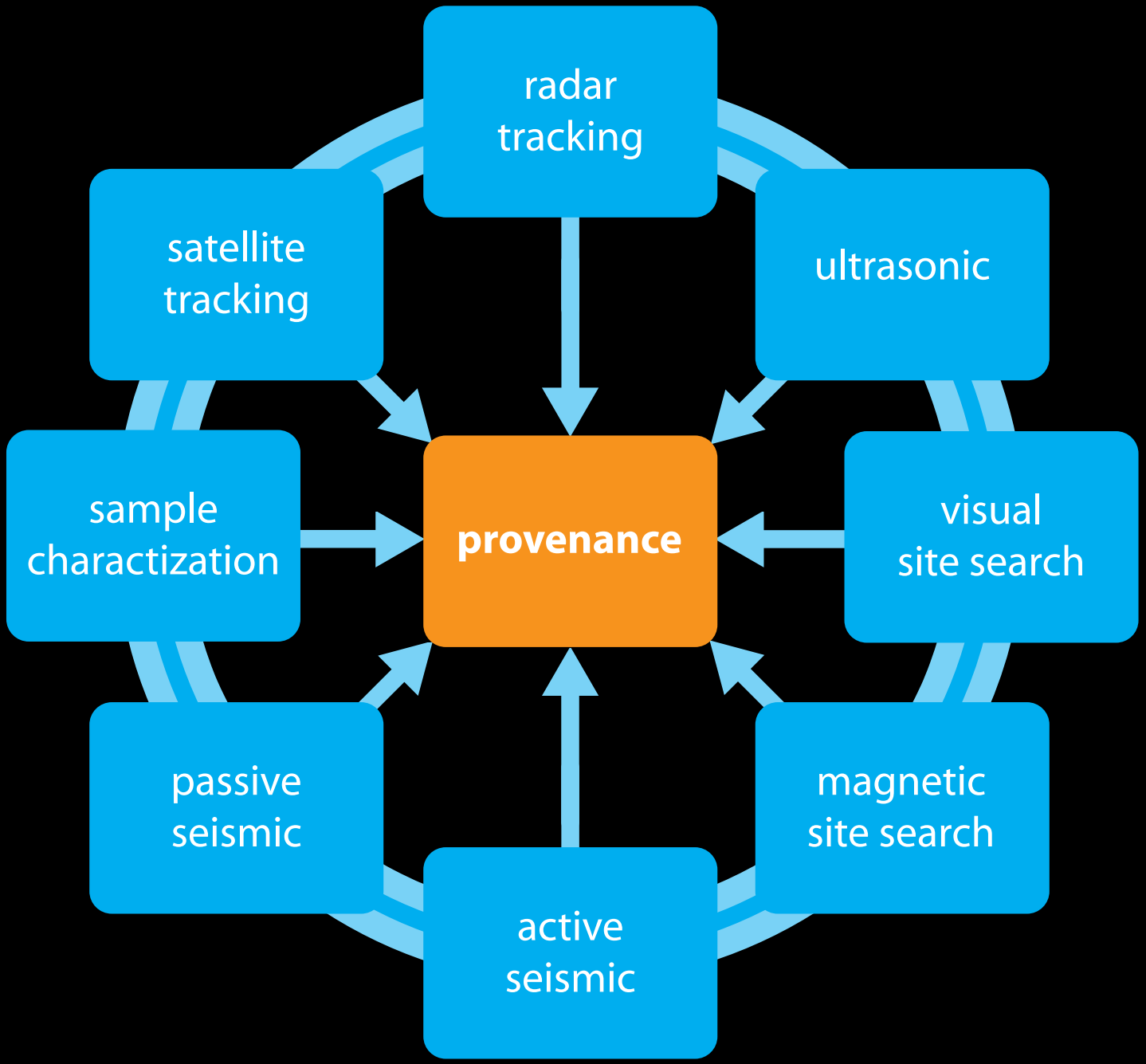

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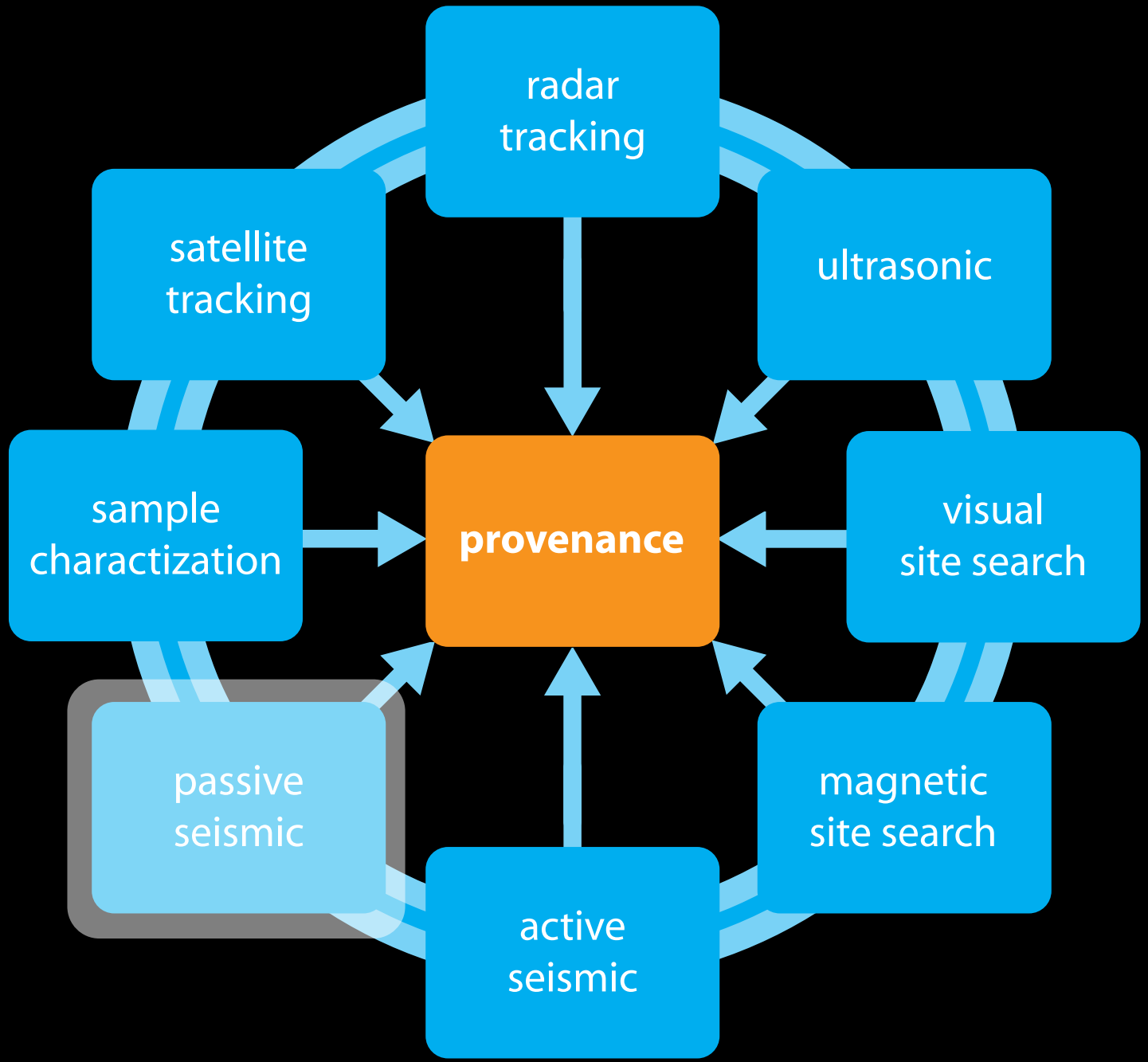

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impact waveform

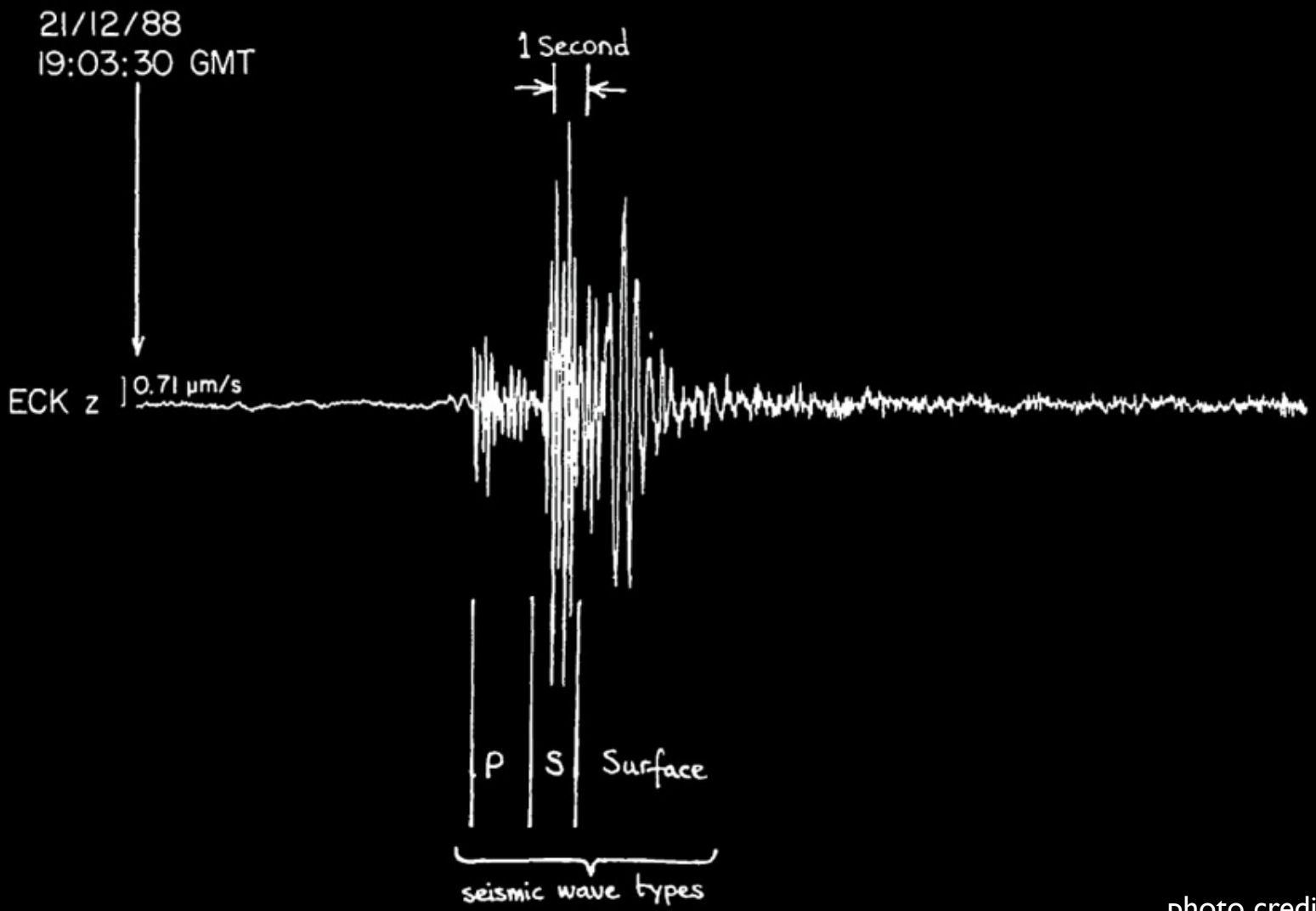

photo credit: Matthews 1990

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earthquake waveform

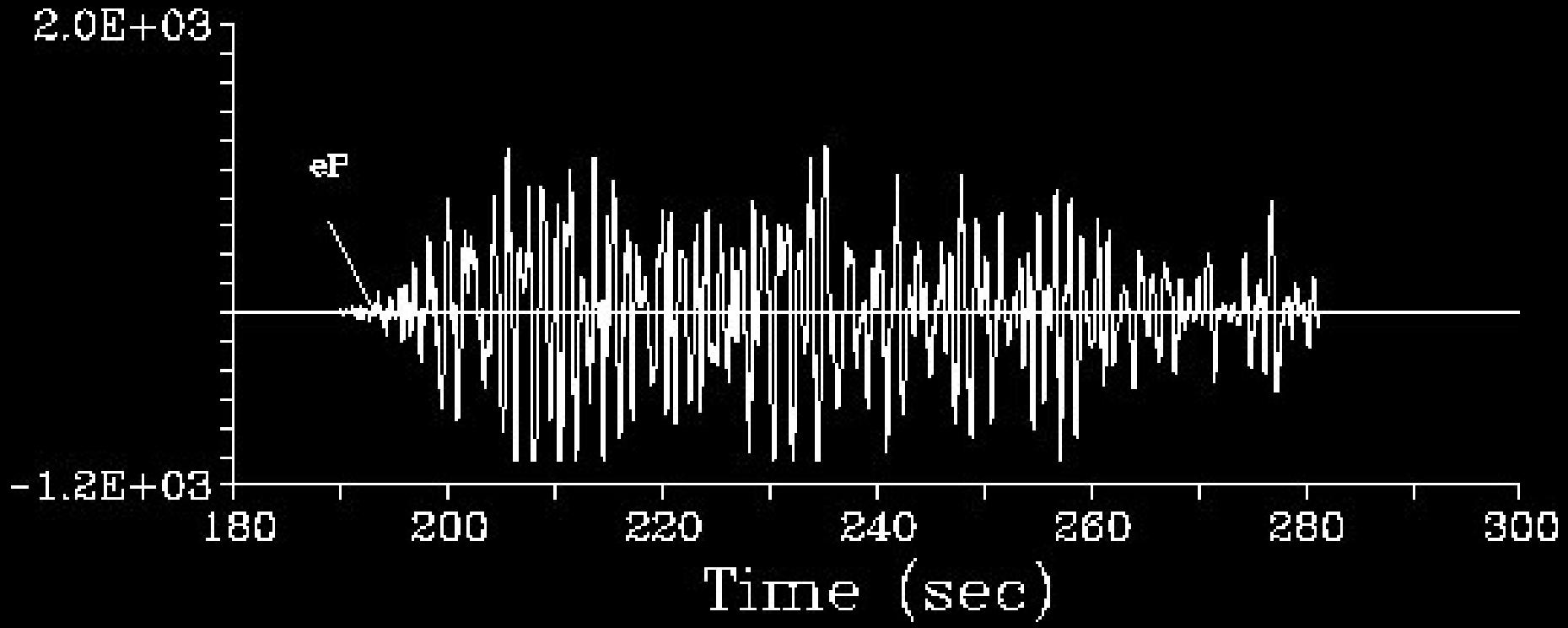

photo credit: USGS

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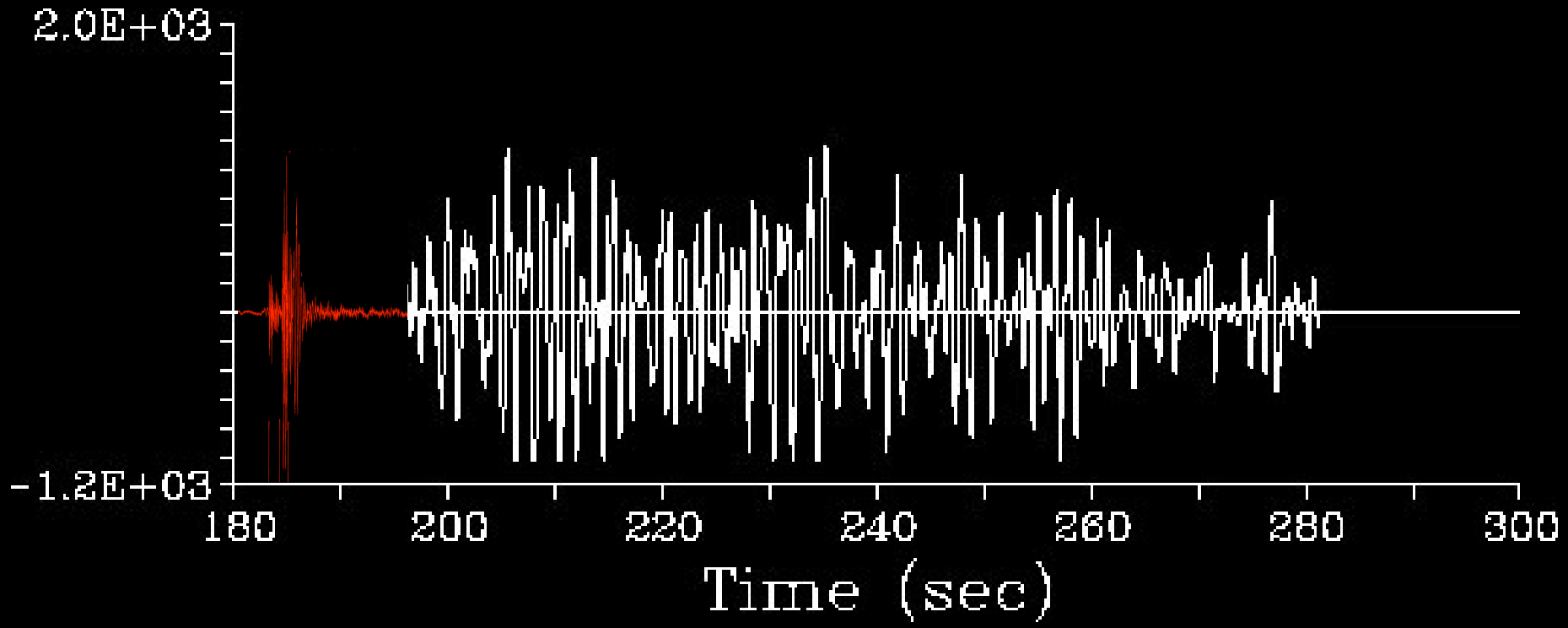
comparison



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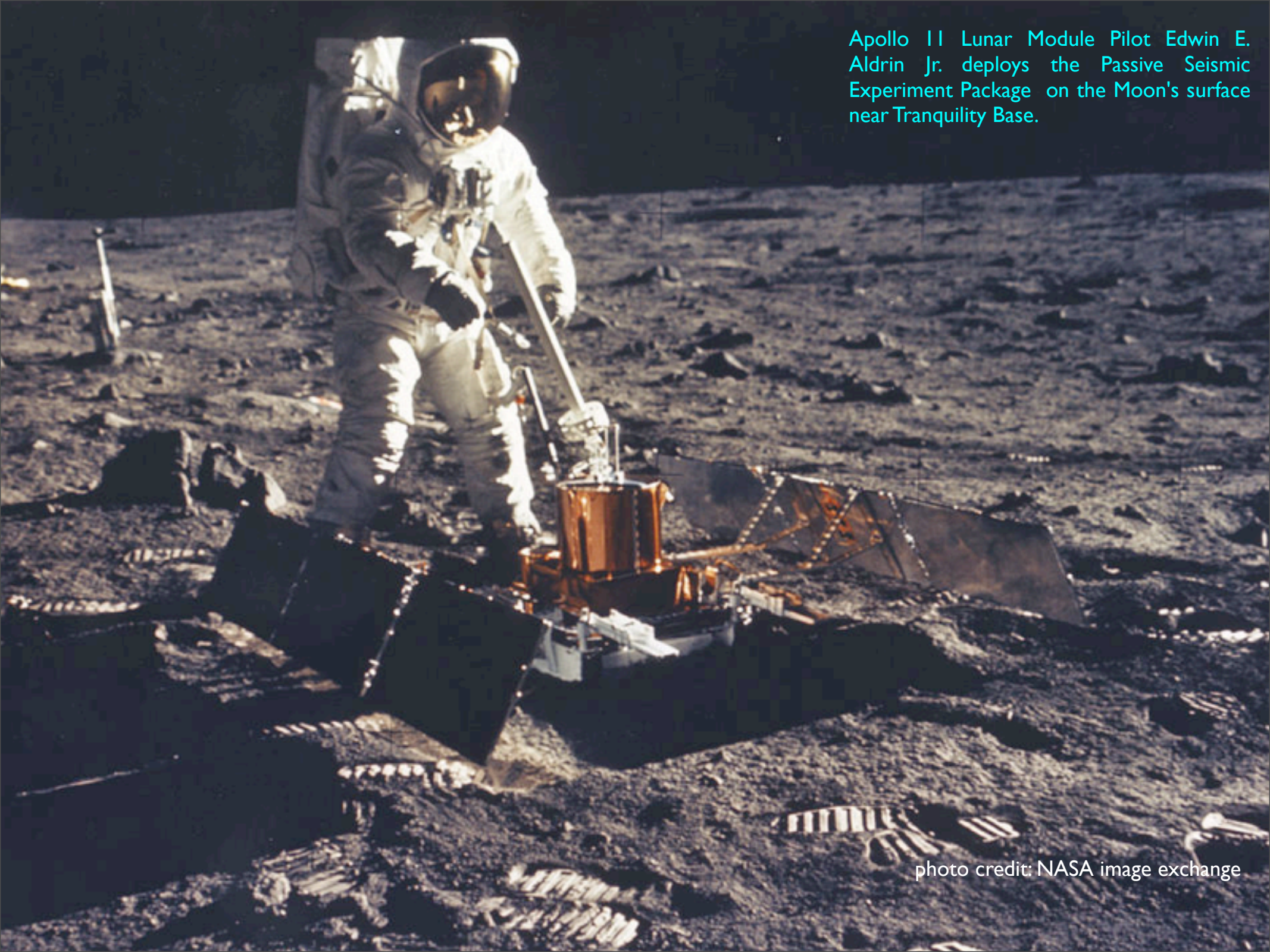
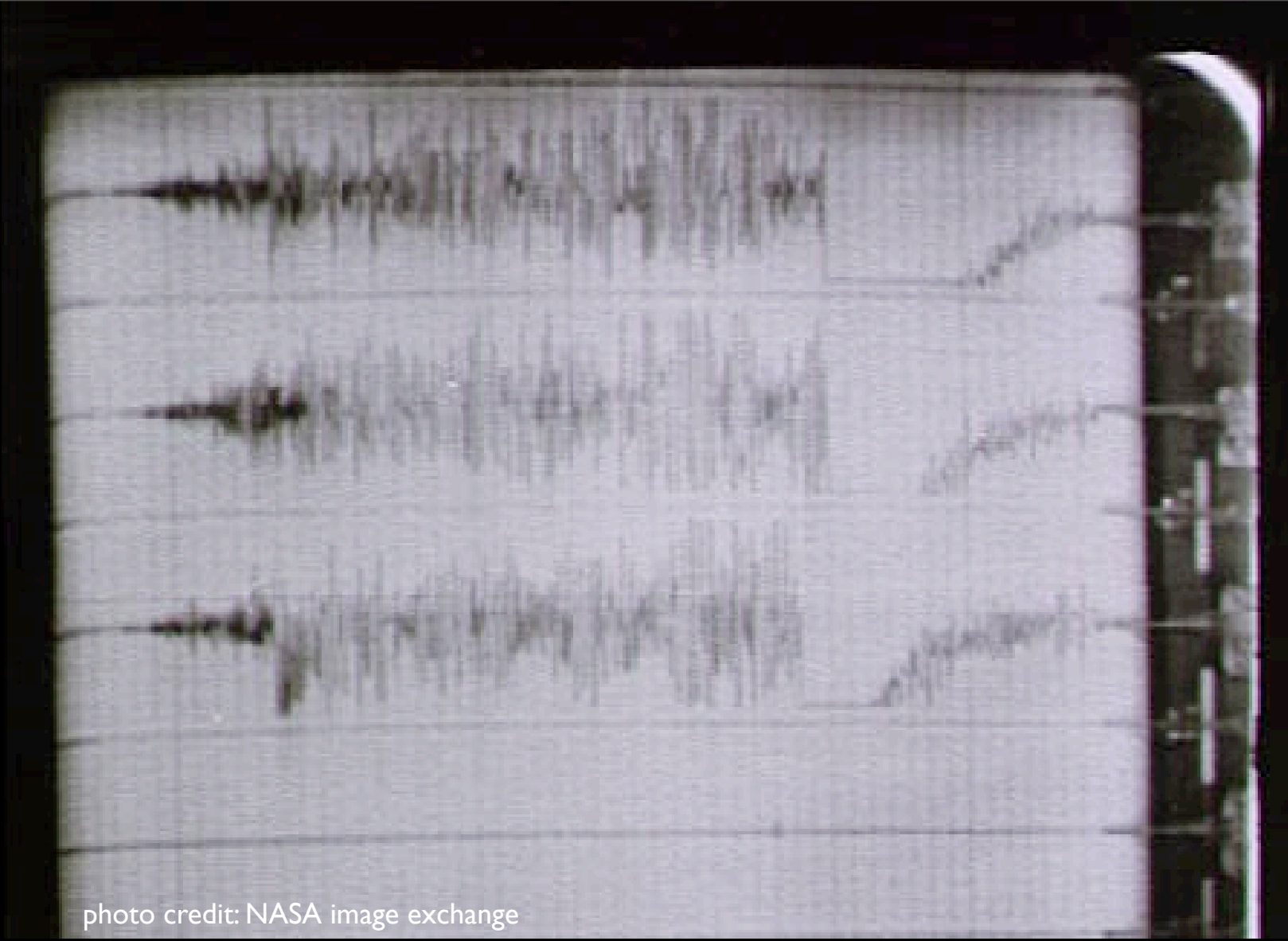


Apollo 11 Lunar Module Pilot Edwin E. Aldrin Jr. deploys the Passive Seismic Experiment Package on the Moon's surface near Tranquility Base.

photo credit: NASA image exchange



A seismic reading taken from instruments at the Manned Spacecraft Center (MSC) recording impact of the Apollo 13 S-IVB/Instrument Unit with lunar surface. The expended Saturn third stage and instrument unit impacted the lunar surface at 7:09 p.m., April 14, 1970. The location of the impact was 2.4 degrees south latitude and 27.9 degrees west longitude, about 76 nautical miles west-northwest of the Apollo 12 Lunar Surface Experiment package deployment site. The S-IVB/IU impact was picked up by the Passive Seismic Experiment, a component of the package and transmitted to instruments at the Mission Control Center.

summary

- meteorite recovery helps to accomplish one of the key goals of space exploration – knowledge of material composition of the solar system and universe as a whole
- innovative uses of proven technology can make this process cost/time effective
- this approach is suitable for initial deployment on earth with a natural progression to moon

earth crescent over lunar horizon
taken by Apollo 15 : NASA image exchange

reinforcements

improved retrieval

- combination of passive (impact) and active (Simulated Impact Device) seismic techniques
- perform high-resolution geologic survey
- reduced search area and impact uncertainty
- characterization by type, mass, velocity prior to retrieval
- successful retrievals can enhance technology

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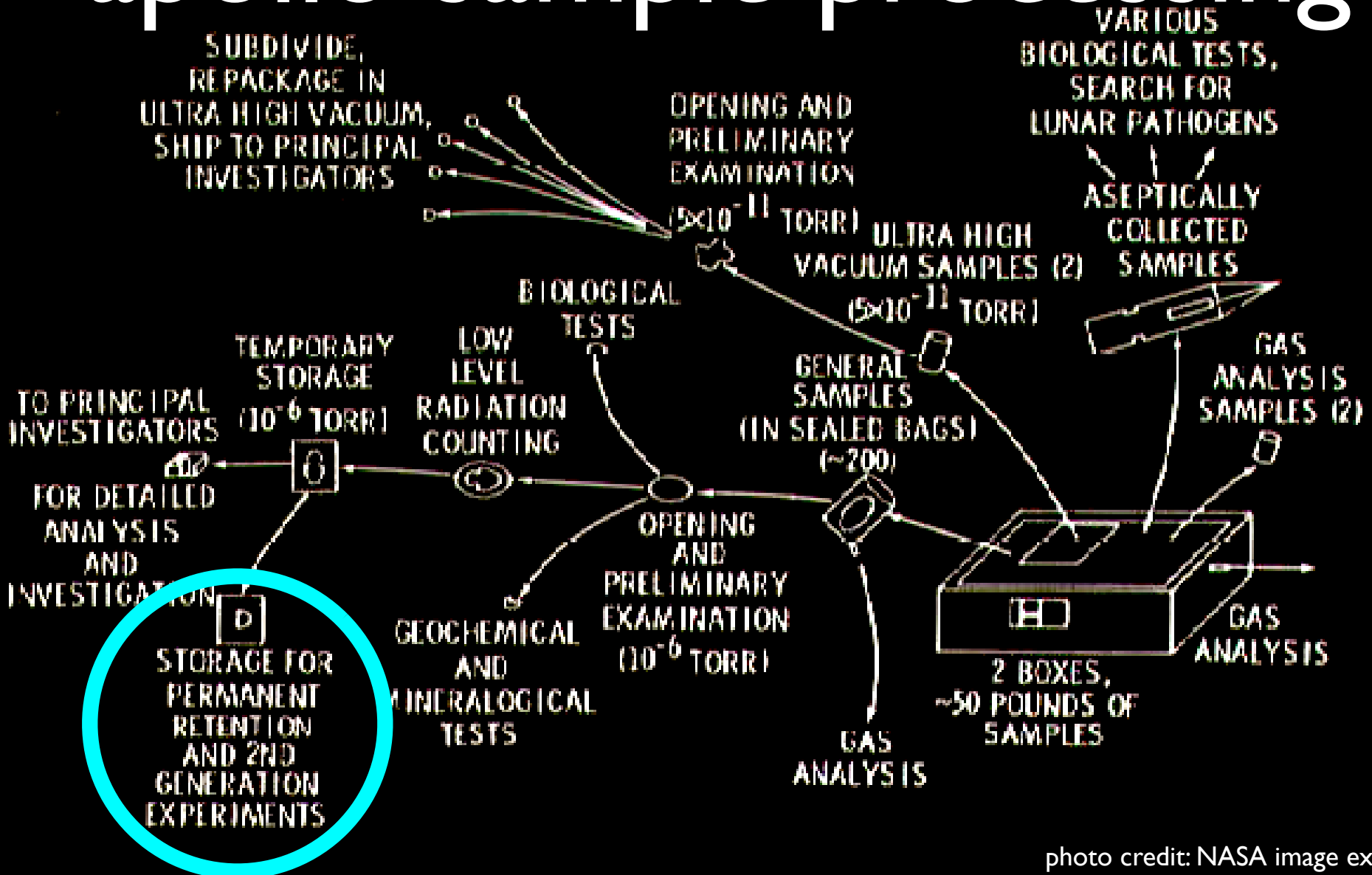
apollo sample processing



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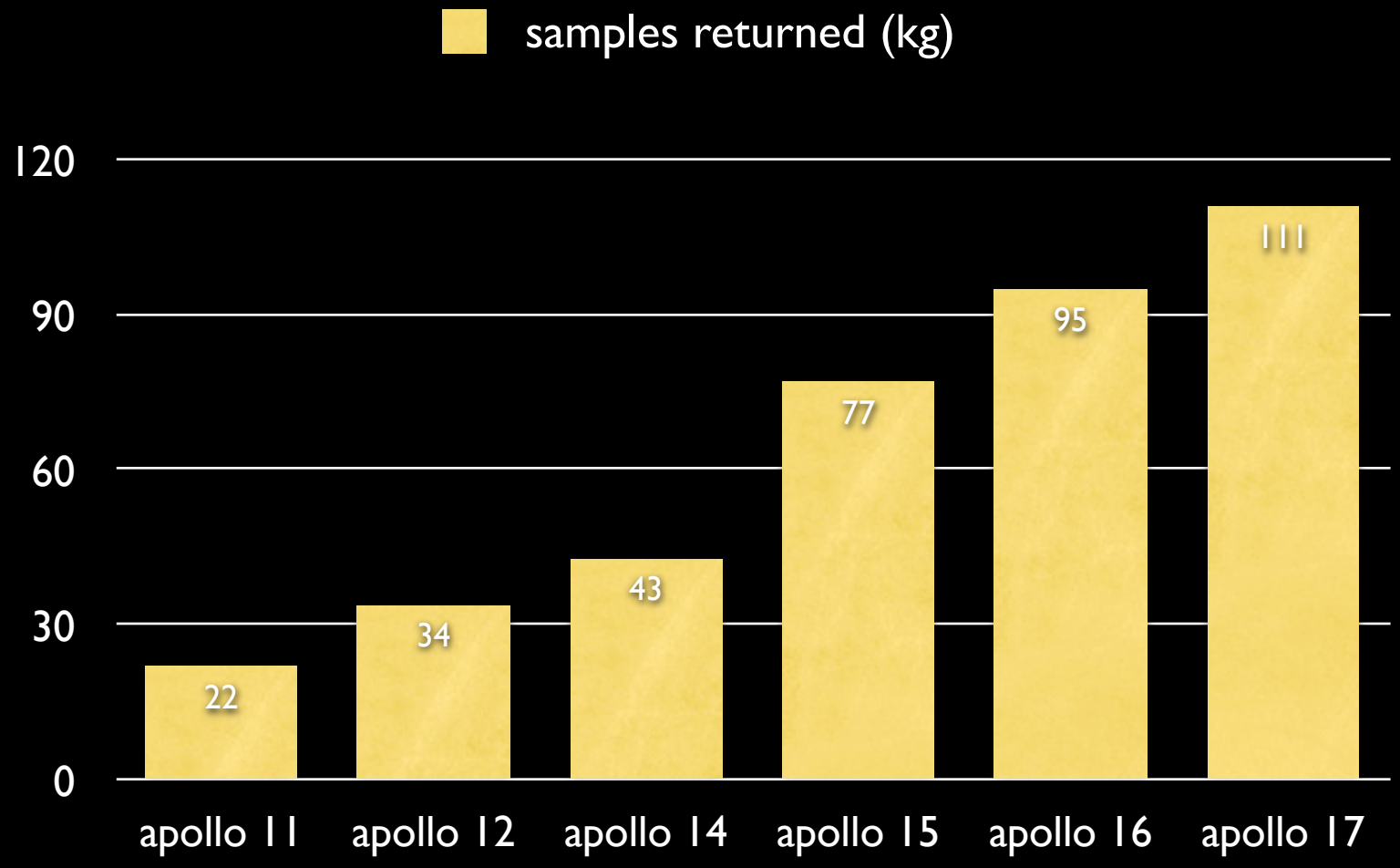
lunar projections



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close-up of astronaut's foot and footprint
during Apollo 11 EVA on lunar surface

taken from command module of Apollo 11
moments before separation for the first lunar landing