THE SKIES OF NORTHERN CHILE: WINDOW TO THE UNIVERSE

R. Chris Smith

AURA Observatory in Chile

CTIO/Gemini/SOAR/LSST

AURA

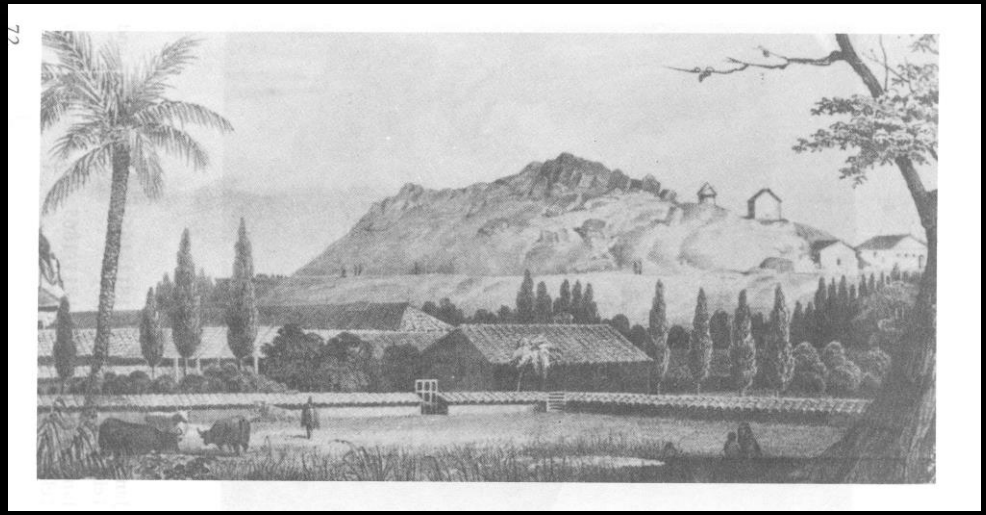
“PRE-HISTORY” OF CHILEAN ASTRONOMY

- The dream of having a National Astronomical Observatory started in 1842
- Bernardo O’Higgins wrote a letter requesting funding from his legacy
- The request didn’t prosper, but the idea was planted…

THE BEGINNINGS OF INTERNATIONAL COLLABORATION

- Astronomical research was begun in 1849, with the arrival of a U.S. Naval expedition

- Cerro Santa Lucia



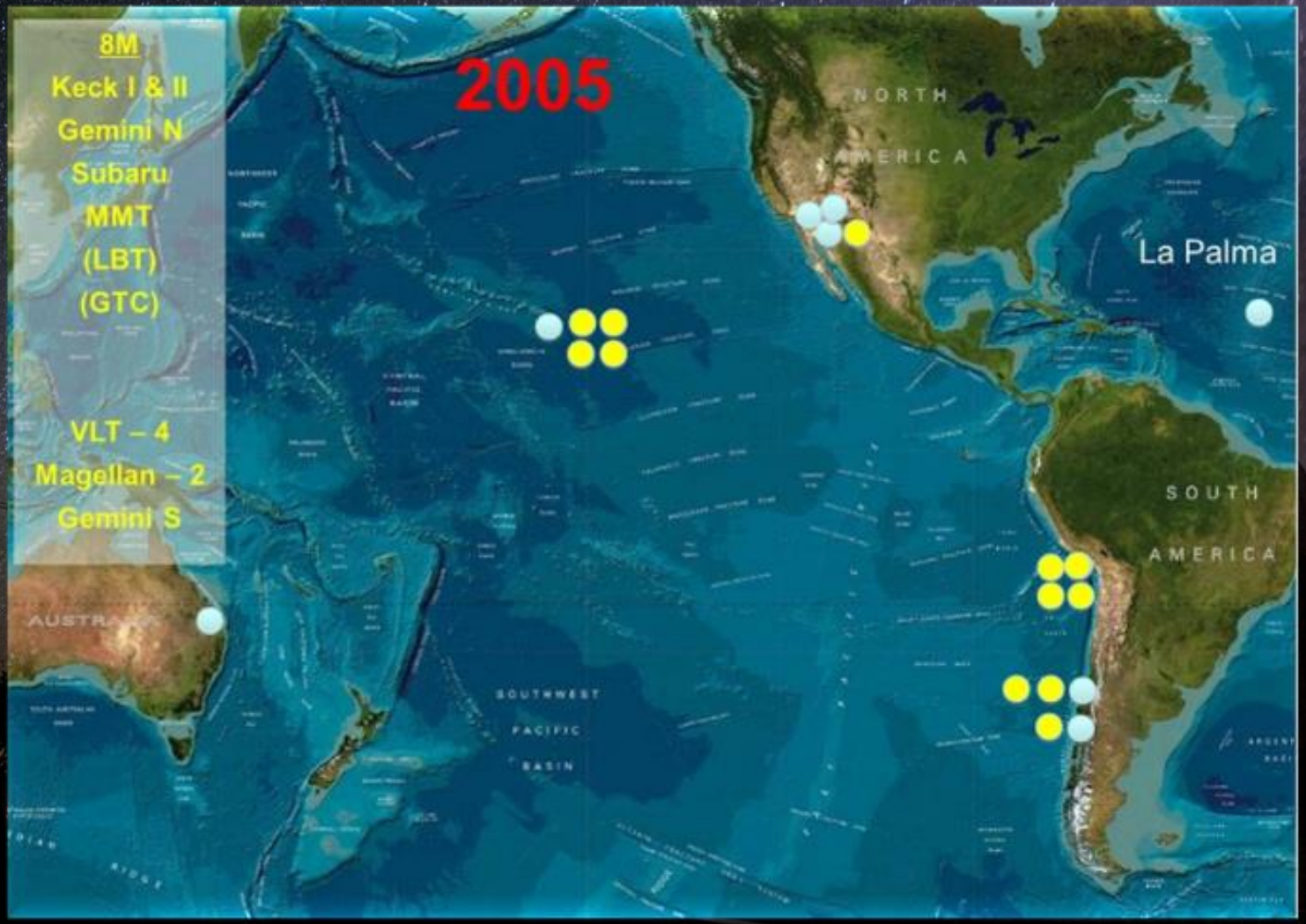
- In 1852, when the expedition finished its work, the Chilean govt. purchased the instruments and established the **Observatorio Astronómico Nacional de Chile**

VISIONARY ADVOCATE OF CHILEAN SKIES: FREDERICO RUTLLANT

Plate 11: Federico Rutllant Alcina (1904-1971), circa 1960.
Lámina 11: Federico Rutllant Alcina (1904-1971), alrededor de 1960.

81

BY 2005, CHILE LEADING IN WORLDWIDE ASTRONOMICAL FACILITIES



MAJOR FACILITIES:
AURA OBSERVATORY IN CHILE

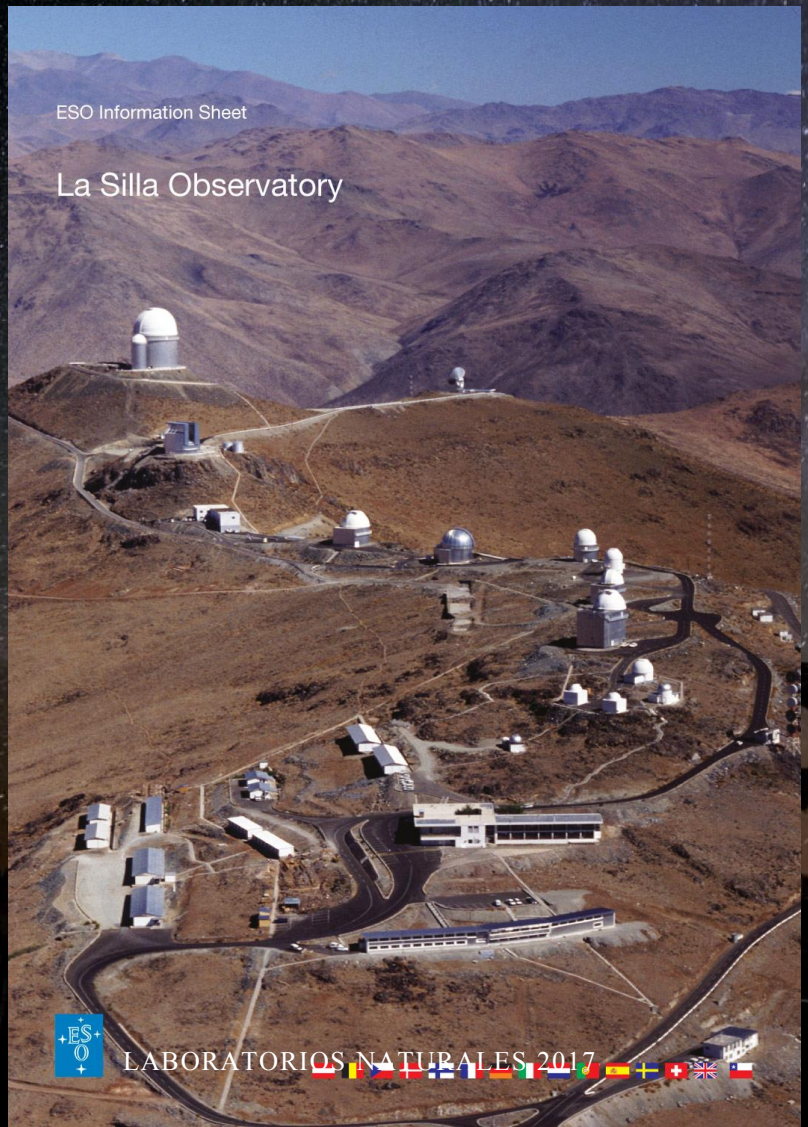
Cerro Tololo

Gemini South

SOAR

MAJOR FACILITIES TODAY: ESO

La Silla



Paranal

MAJOR FACILITIES TODAY: CARNEGIE

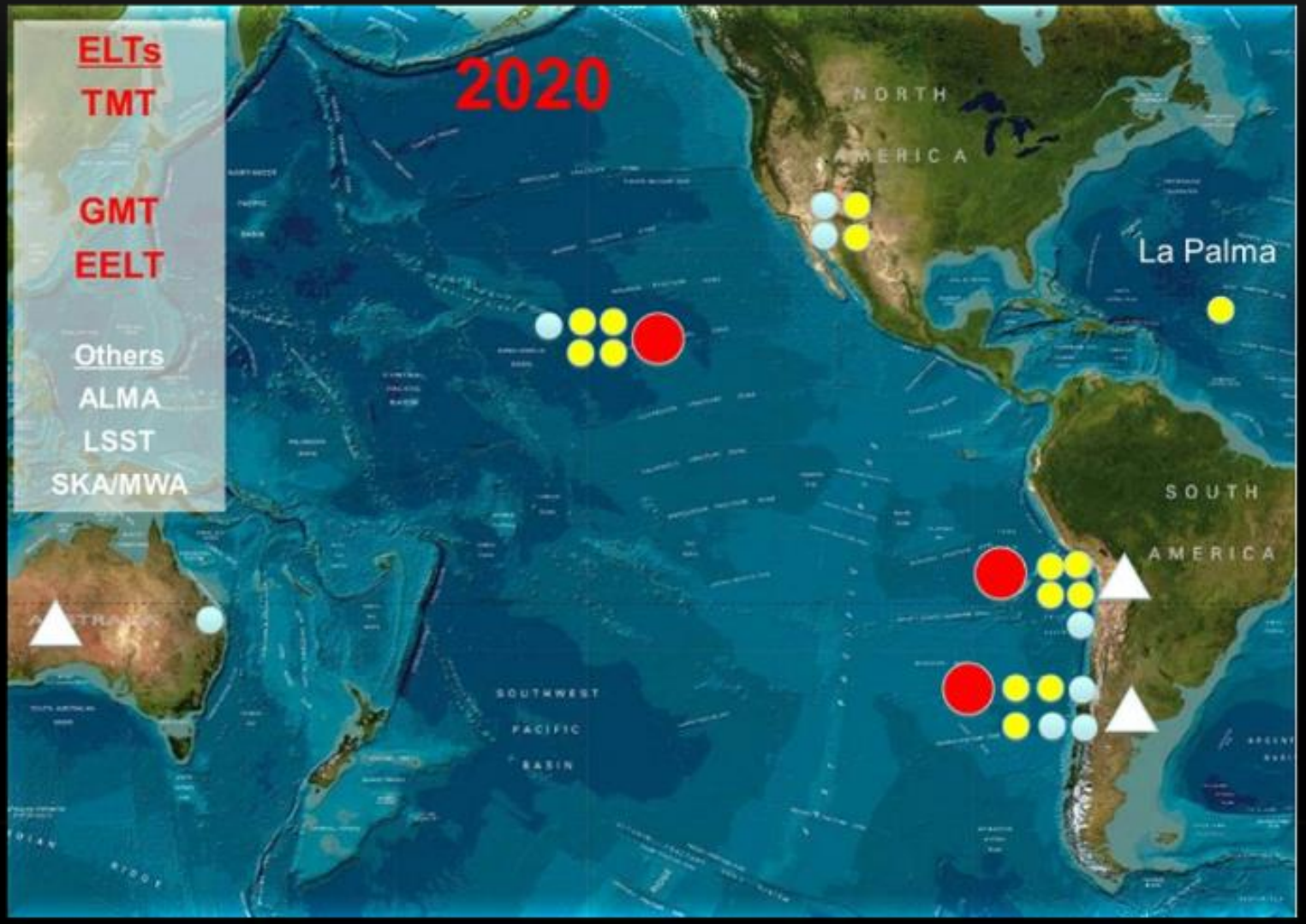
Las Campanas Observatory

Ma

THE NEXT WAVE…

- Every ~20 years we have embarked on a new generation of telescopes…
  - 1970s - 1980s = 3-4 meters
  - 1990s - 2010s = 6-10 meters
  - 2010s - 2030s =
    - New windows (wavelength & time)
    - Larger collecting areas
- 2010-2030: **A new era of discovery space**

BY MID-2020S, CHILE WILL HOST ~70% OF ASTRONOMICAL COLLECTING AREA

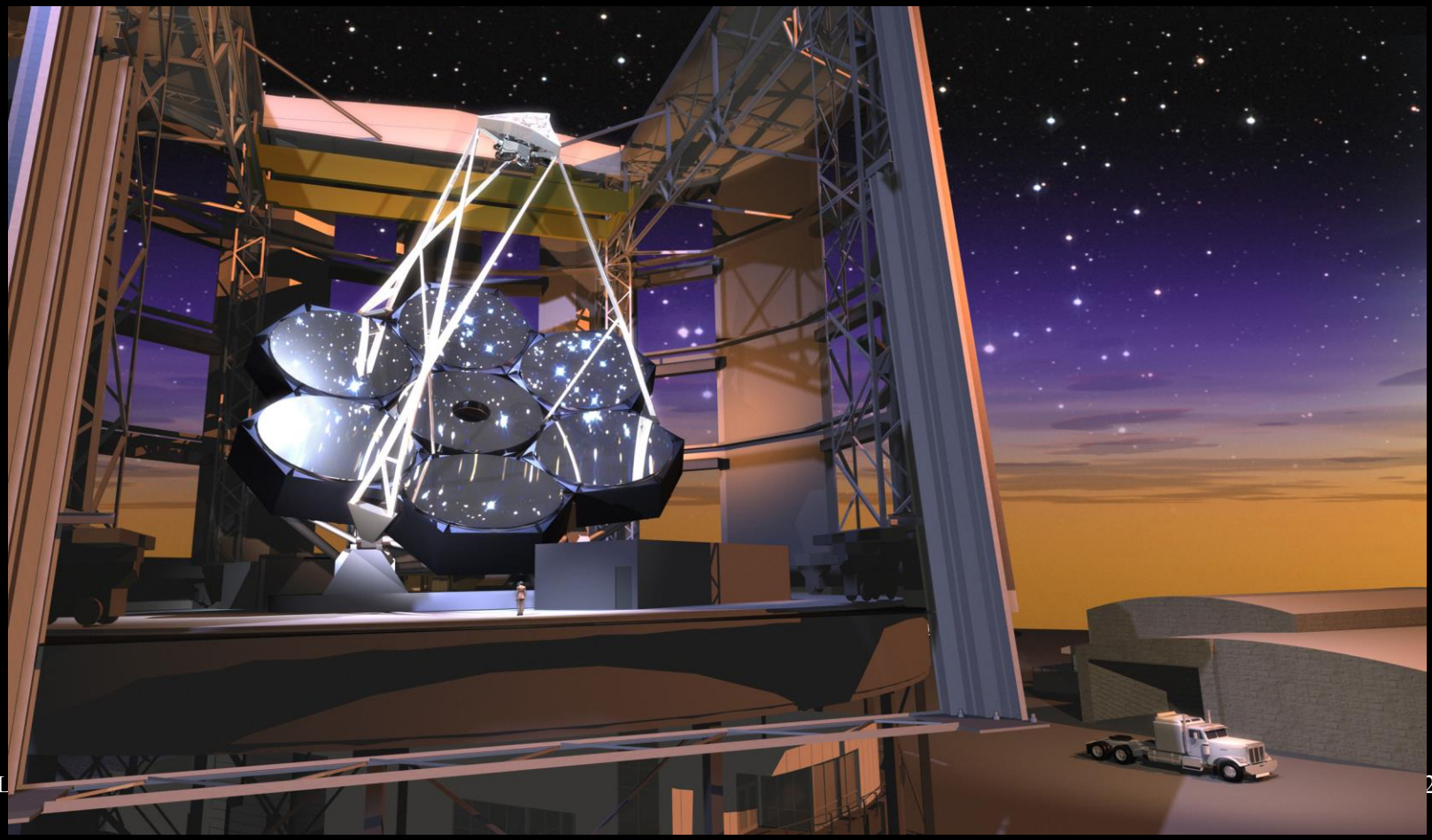


ALMA: ATACAMA LARGE MILLIMETER ARRAY

- >60 antennas in the high plains of Northern Chile; largest astronomical facility ever undertaken

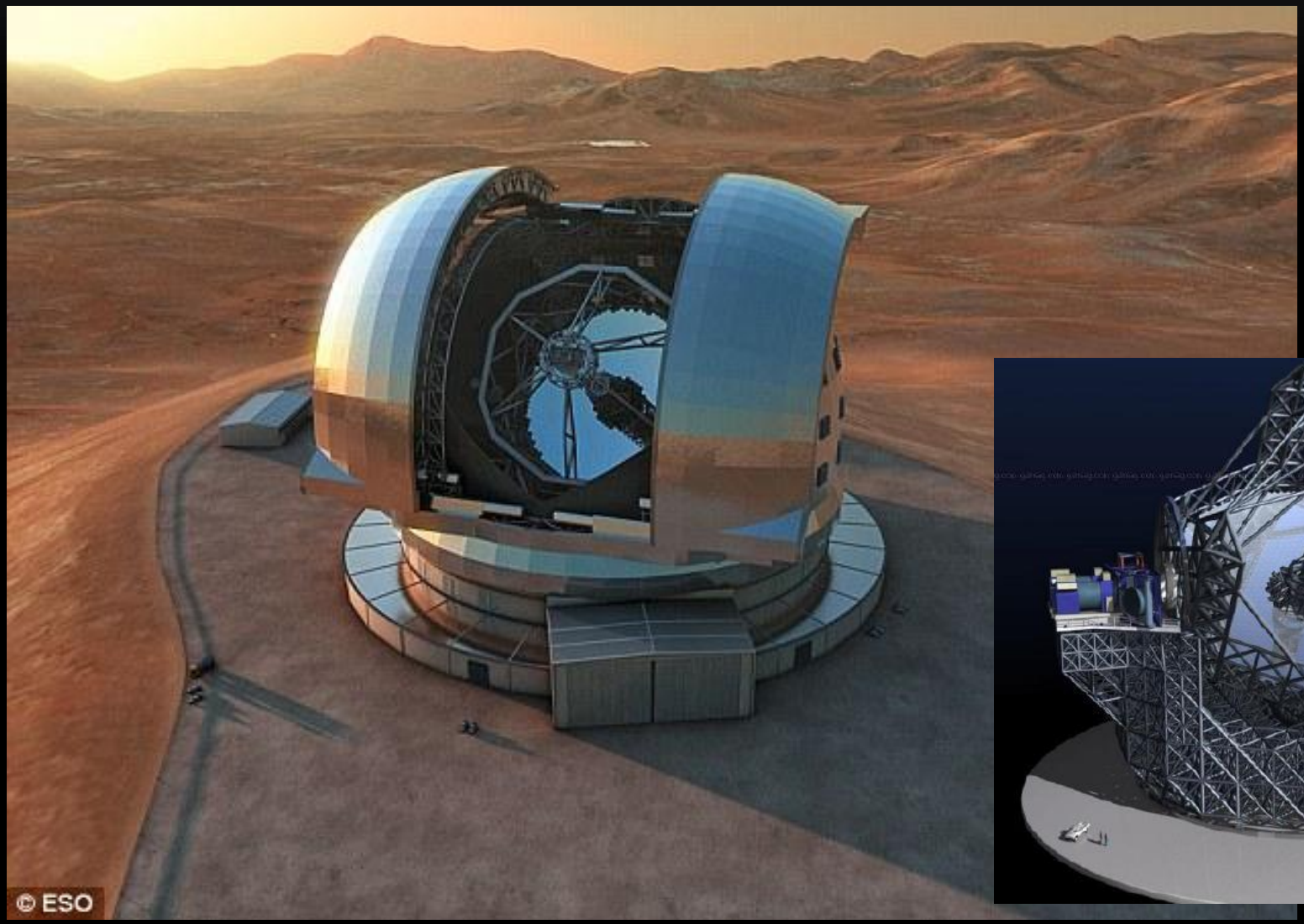
GMTO (CARNEGIE++)

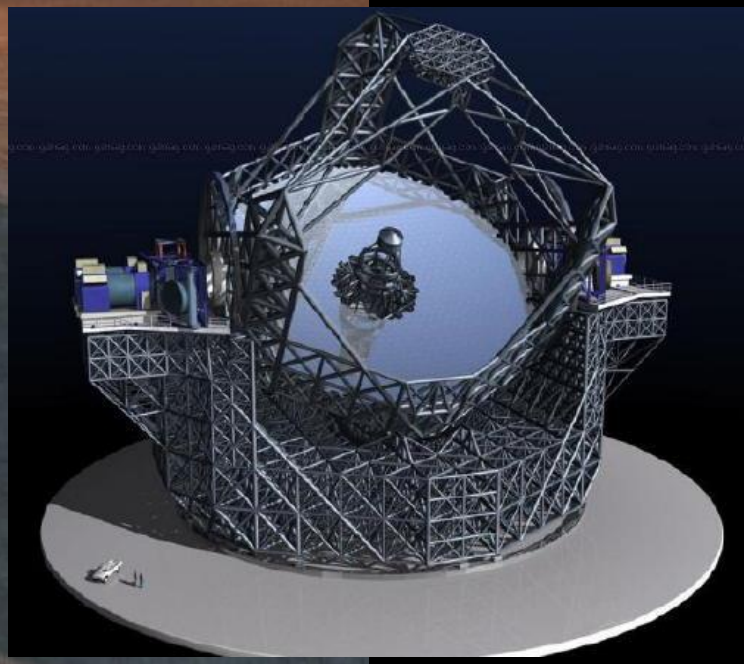
- Giant Magellan Telescope
  - 7 x 8.4m mirrors = 25m collecting area



E-ELT (ESO)

- European Extremely Large Telescope (39m)





WHY CHILE?

- High sites: Andes
- Stable air: smooth flow from Pacific, producing sharp images
- Clear skies: dry desert, few cloudy nights
- **Dark** skies (need to keep them that way!)
  - Dark in Optical, “Dark” in Radio as well
- Collaboration, Infrastructure & Commitment

SUCCESSFUL NATURAL LABORATORY: MORE THAN JUST CLEAR SKIES!

- Leadership
  - Identifying opportunities (RUTLLANT)
- Collaboration
  - Supporting site surveys
  - Creating critical mass of peers (developing the field)
- Infrastructure
  - Complex projects need significant infrastructure support

SUCCESSFUL NATURAL LABORATORY: COMMITMENT

- Universities
  - Training both technical and research staff
  - Critical mass of researchers to participate in endeavor
- Government
  - Creating favorable conditions for development
  - Protecting natural conditions

PROTECTING DARK SKIES

REPÚBLICA DE CHILE
MINISTERIO DEL MEDIO AMBIENTE

TESE, TÓMESE RAZÓN Y PUBLÍQUESE

ESTABLECE NORMA DE EMISIÓN PARA LA REGULACIÓN DE LA CONTAMINACIÓN LUMÍNICA, ELABORADA A PARTIR DE LA REVISIÓN DEL DECRETO SUPREMO N°686, DE 1998, DEL MINISTERIO DE ECONOMÍA, FOMENTO Y RECONSTRUCCIÓN.

CONTRALORIA GENERAL TOMA DE RAZON
28 MAY. 2013
EPCION

DECRETO N° 043

SANTIAGO, 17 DIC. 2012

SEBASTIÁN PIÑERA ECHENIQUE
Presidente de la República

MINISTERIO DE ECONOMIA FOMENTO Y TURISMO
MINISTRO

PABLO LONGUEIRA MONTES
Ministro de Economía, Fomento y Turismo

MINISTERIO DE ECONOMIA, FOMENTO Y TURISMO
DIVISION JURIDICA
CHILE

MINISTERIO DEL MEDIO AMBIENTE
MINISTRA

MARIA IGNACIA BENÍTEZ PEREIRA
Ministra del Medio Ambiente

V1: 1998
V2: published 2013 Mayo 5,
With restrictions on spectrum, total light, and active LED signs

SUCCESSFUL NATURAL LABORATORY: BROADENING IMPACTS

- Astro-tourism
  - Direct economic impacts
  - Potential societal impact: scientifically literate society
- Astro-engineering
  - Development of advanced human capital
  - Potential spin-off technologies & initiatives
- Astro-informatics


LINKING FRONTIERS IN BIG DATA:
BIG DATA IN ASTRONOMY & LSST

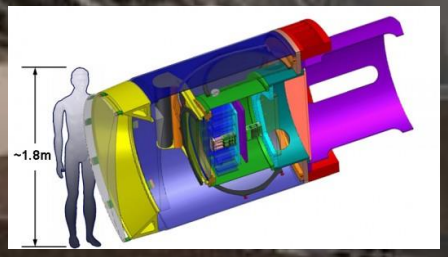
THE NEXT STEP – MASSIVELY PARALLEL ASTROPHYSICS

Survey the entire sky every 3-4 nights, to simultaneously detect and study:

- Dark Matter via Weak gravitational lensing
- Dark Energy via thousands of SNe per year
- Potentially hazardous near earth asteroids
- Tracers of the formation of the solar system
- Fireworks in the heavens – GRBs, quasars…
- Periodic and transient phenomena
- … the UNKNOWN

Next Step: LSST
Creating a "Digital Universe"

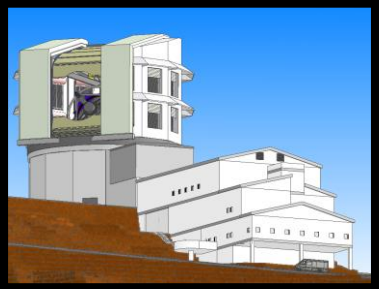
LSST is designed to image the whole sky every few nights for 10 years, giving us a movie-like window into our dynamic Universe.



- 8.4 M Telescope
  - 3.5 Degree Field Of View
  - Telescope Located in Chile on Cerro Pachón
- 3.2 Billion Pixel Camera
- ~40 Second Cadence
  - Two 15 second exposures
  - Full sky coverage every few nights
- Advanced Data Management Systems
- Public Data
  - Alerts of new events
  - Catalogs of object
  - Archives of images

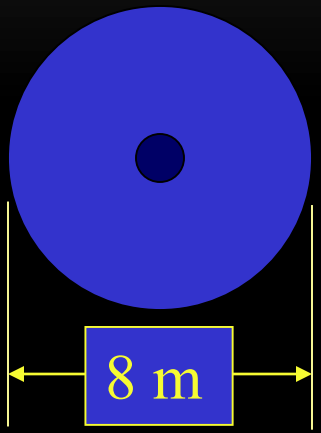
WHY IS THE LSST SO UNIQUE?

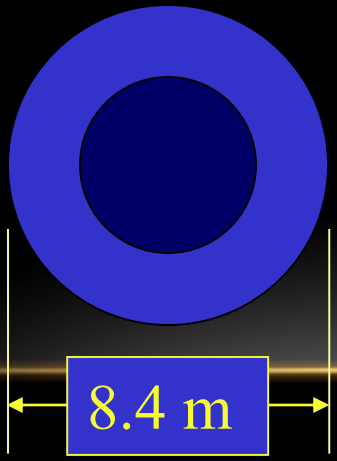
Gemini South Telescope



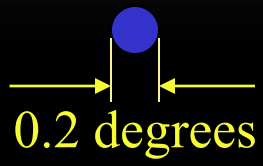
LSST

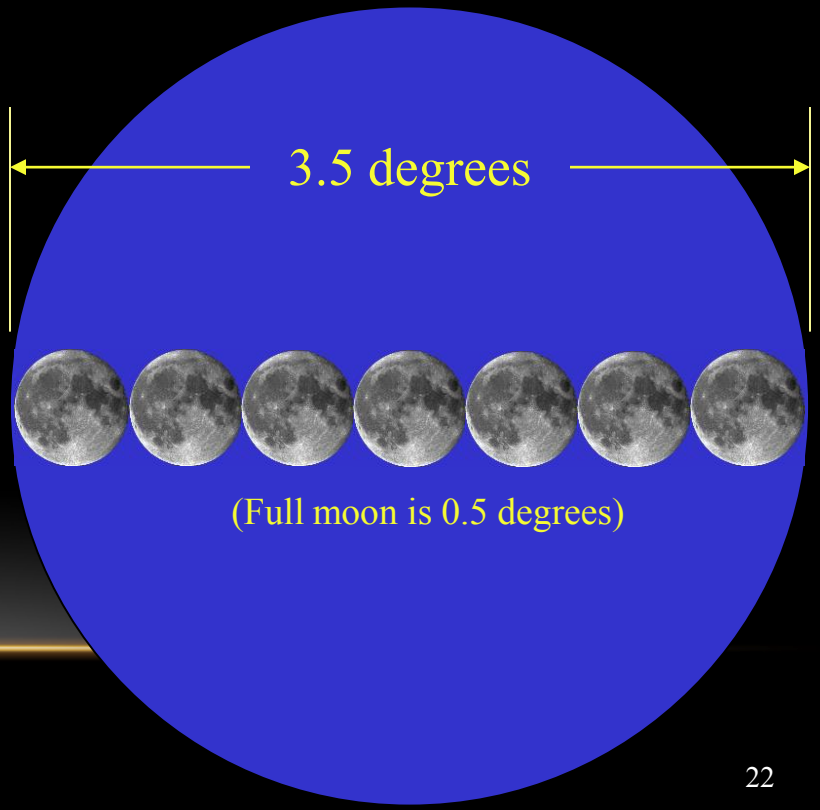
Primary Mirror Diameter





Field of View





TELESCOPE AND SITE

30 m diameter dome

1.2 m diameter atmospheric telescope

Control room and heat producing equipment (lower level)

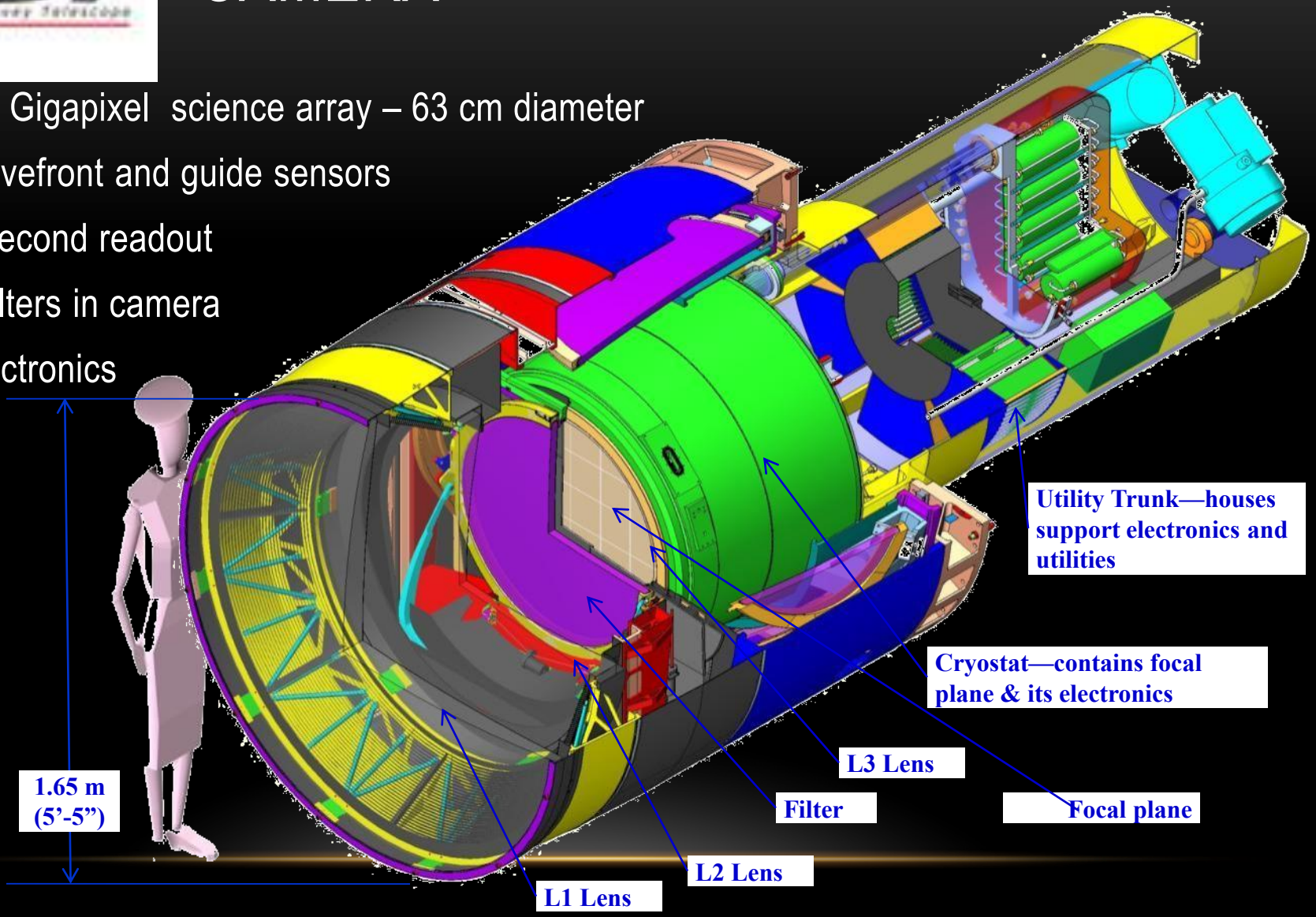
1,380 m^2 service and maintenance facility

Base Facility

Project includes the facilities, and hardware to collect the light, control the survey, calibrate conditions, and support all LSST summit and base operations.

CAMERA

- 3.2 Gigapixel science array – 63 cm diameter
- Wavefront and guide sensors
- 2 second readout
- 5 filters in camera
- Electronics



LSST: A CASE STUDY FOR PETASCALE DATA MANAGEMENT

- Each image roughly 12GB
- Cadence: 1 image every ~18s
- 15 to 18 TB per night, 30TB “reduced”!
  - ALL must be transferred to US @NCSA archive center
    - within image timescale (<5s), >>10 Gbps
- REAL TIME reduction, analysis, & alerts
  - Send out alerts of transient sources within 60s
    - ~10 million events per night every night for 10 years
  - Provide automatic data quality evaluation, alert to problems
  - Change survey observing strategy on the fly based on conditions, last field visited, etc.

Data Management Sites and Centers

HQ Site
HQ Facility

Observatory Management
Science Operations
Education and Public Outreach

AURA

LSST Corporation

Archive Site
Archive Center

Alert Production
Data Release Production
Calibration Products Production
EPO Infrastructure
Long-term Storage (copy 2)

Data Access Center

Data Access and User Services

French Site
Processing Center

Data Release Production
(Proposed)

Summit Site
Summit Facility

Telescope and Camera
Data Acquisition
Crosstalk Correction

Base Site
Base Facility

Long-term storage (copy 1)

Data Access Center

Data Access and User Services

“BIG DATA”
NOT JUST IN SIZE, BUT ALSO COMPLEXITY

- Astronomy moving from
  - GB datasets (1990 - 2010) to
  - TB datasets (2010 - 2020) to
  - PB datasets (2020 - …)
- Moving from measurements of just “brightness” to measurements of “photo-z”, “shapes”, and automated classifications of objects
- Requires:
  - Network Connectivity
  - Data Processing & Storage
  - Advanced Analysis Techniques (Data Mining)

LSST From the User's Perspective

Level 1

- A stream of ~10 million time-domain events per night, detected and transmitted to event distribution networks within 60 seconds of observation.
- A catalog of orbits for ~6 million bodies in the Solar System.

Level 2

- A catalog of ~37 billion objects (20B galaxies, 17B stars), ~7 trillion observations ("sources"), and ~30 trillion measurements ("forced sources"), produced annually, accessible through online databases.
- Deep co-added images.

Level 3

- Services and computing resources at the Data Access Centers to enable user-specified custom processing and analysis.
- Software and APIs enabling development of analysis codes.

CONSTRUCTION NOW
FIRST LIGHT IN 2020
OPERATIONS IN 2022

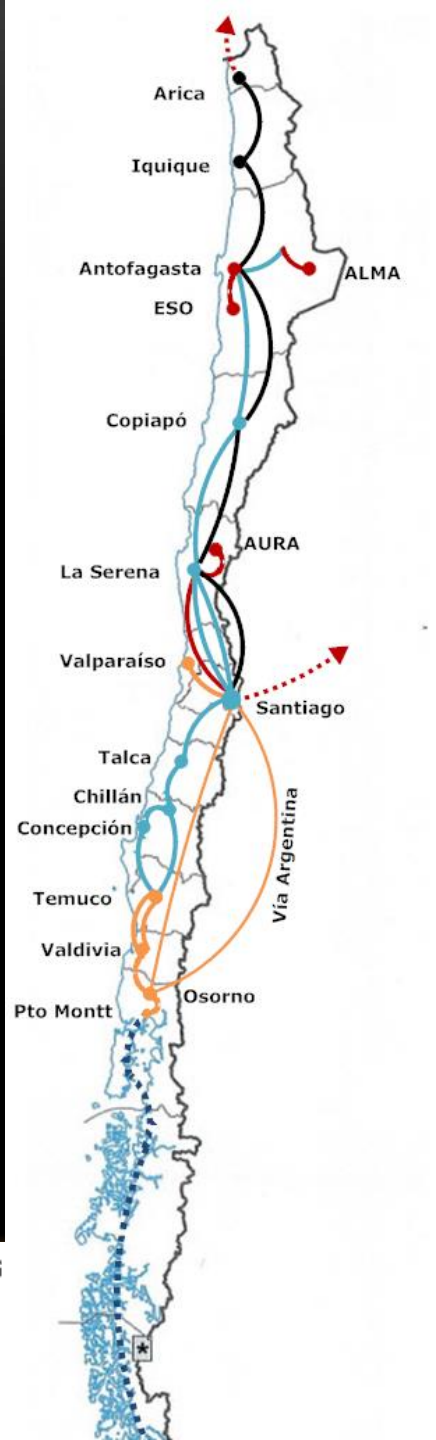
KEY STRATEGIC OPERATIONAL PARTNERSHIPS

- Connectivity @100Gbps+
  - High-speed Chilean bandwidth (REUNA)
  - International bandwidth (AmLIGHT, RedCLARA)
- Distributed Computing Systems
  - Supercomputer center(s) to provide bulk storage, large scale processing (e.g., NCSA, NLHPC, PUC, Others)
  - Effective access to data products through Data Access Centers (DACs)
  - Grid processing, storage, advanced DBs

Goal: Provide **effective** access to data products and analysis resources for scientists as well as public users

REUNA: A DIGITAL HIGHWAY FOR RESEARCH & EDUCATION IN CHILE

- Working with AURA, ESO, & ALMA
- Building on opportunities & partnerships (both with Observatories and Industry)
  - AURA – Key network infrastructure in ~2005
  - ESO – 10Gbps Lambda from Antofagasta to Santiago (EVALSO) in 2011
  - ALMA – Fiber installation from Calama to Site (and to Argentina) in 2015
  - AURA – Fiber from Santiago to La Serena in 2017 (100Gbps x 2+)



KEY STRATEGIC SCIENTIFIC PARTNERSHIPS

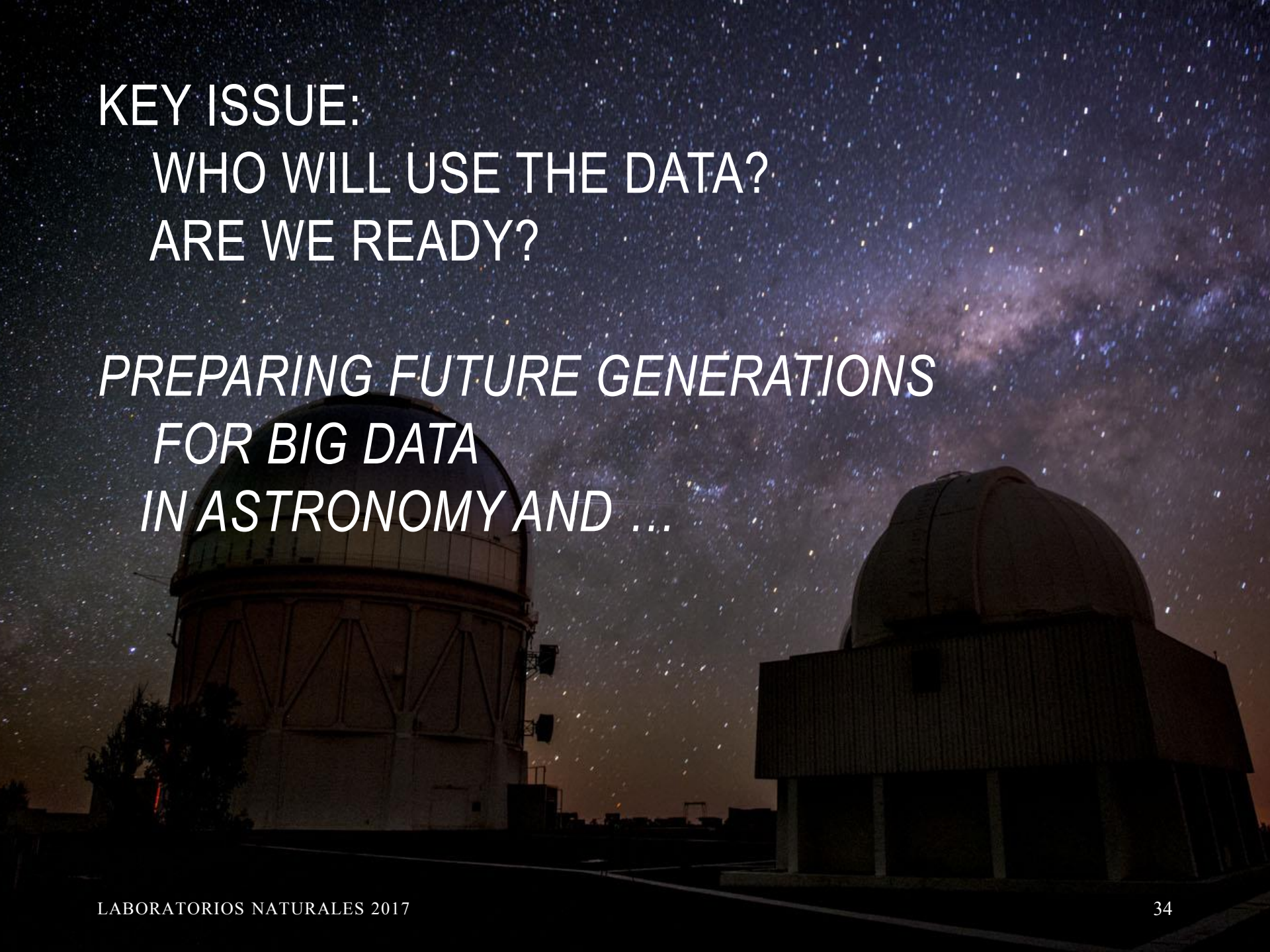
- Scientific Analysis Challenges:
  - Automatically finding unique objects: one in billions
  - Separating small signals from systematic effects
  - Limiting, if not eliminating, false positives in multiple dimensions (time, space, color, etc.)
  - Combining peta-scale datasets in complex ways
- *Requires techniques that deal with both **quantity** and **quality** of data*
  - Partnerships with CMM, MAS, & others

THE SCIENCE OF BIG DATA

- Data growing exponentially, in all sciences
- Changes the nature of science

  from hypothesis-driven to data-driven discovery
- Cuts across all sciences
- Industry and government face the same challenges
- Convergence of physical and life sciences through Big Data (statistics and computing)
- A new scientific revolution

Data-to-Knowledge



KEY ISSUE:

WHO WILL USE THE DATA?

ARE WE READY?

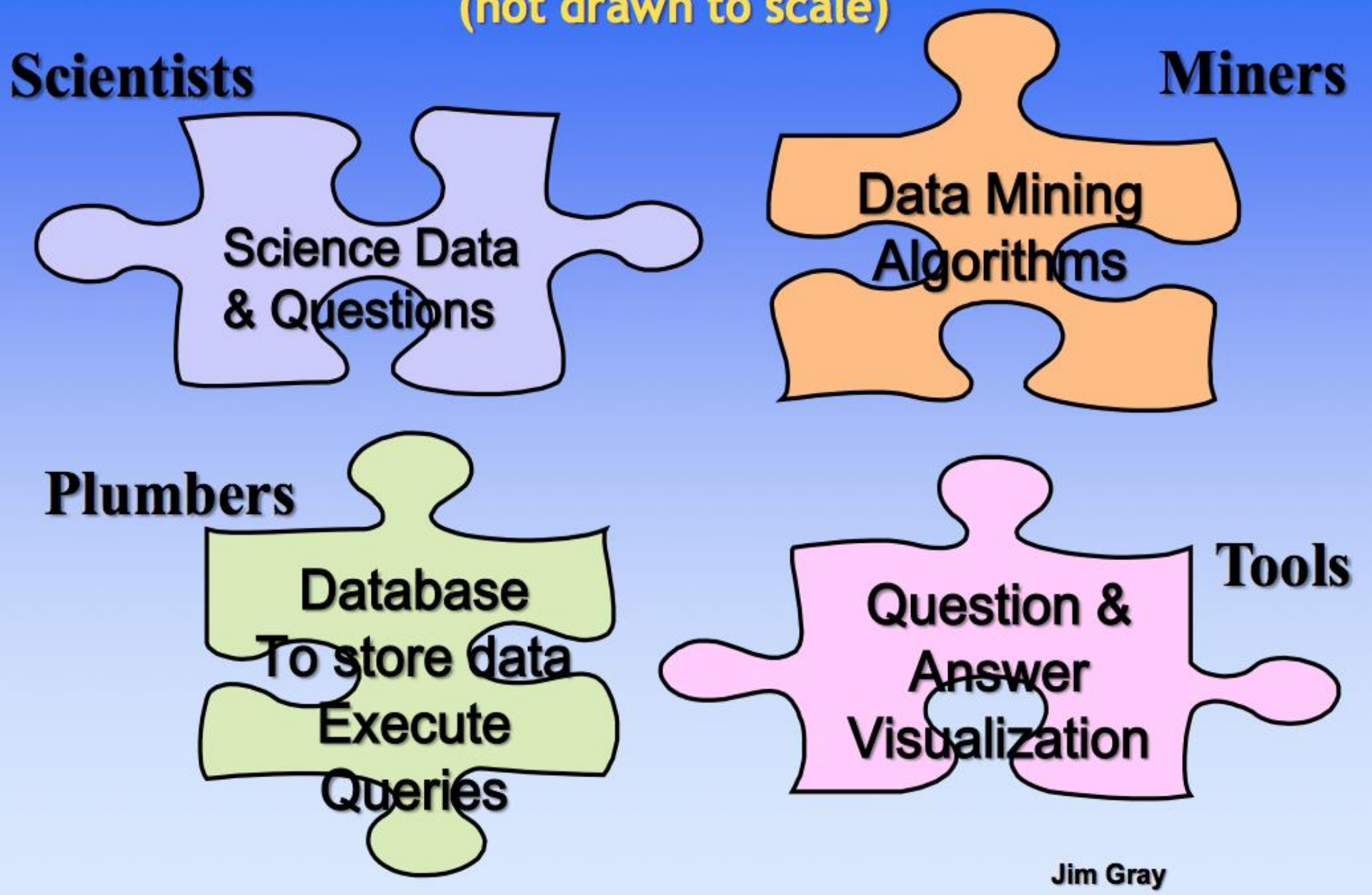
PREPARING FUTURE GENERATIONS

FOR BIG DATA

IN ASTRONOMY AND …

What's needed?

(not drawn to scale)



Jim Gray

LSST OUTREACH DATA WILL BE USED IN CLASSROOMS, SCIENCE MUSEUMS, AND ONLINE

Classroom Emphasis on:

- Data-enabled research experiences
- Citizen Science
- College classes
- Collaboration through Social Networking

ZOONIVERSE
REAL SCIENCE ONLINE

La Serena School for Data Science 2017

Applied Tools for Data-driven Sciences

- AURA Campus
  La Serena - Chile

Astronomy + Bioinformatics

- *Training the next generation of scientists (in fields of astronomy, bioinformatics, mathematics, computer science, and others) in the tools and techniques of massive data*
- *Target students: senior undergraduate and beginning graduate students*
- *Leaders: Matthew Graham, Amelia Bayo, Mauricio Cerda, Chris Smith, Eduardo Vera*

http://www.aura-o.aura-astronomy.org/winter_school/


CMM Pucón Symposium
5th CMM Pucón Symposium
Data Science for Frontier Astronomy, Biology and Medicine
August 30 - September 2, 2017
Hotel Bellavista
Puerto Varas - Chile
http://eventos.cmm.uchile.cl/pucon2017
Organizers:
CMM Center for Mathematical Modeling
NLHPC National Laboratory for High Performance Computing Chile
Sponsors:
AURA
LSST
ALMA
CONICYT
MILLENNIUM INSTITUTE OF ASTROPHYSICS
fcfm
REUNA
Ciencia y Educación en Red
BIOMEDICAL NEUROSCIENCE INSTITUTE
CORFO

New deadline for Oral Presentations and Focus Demos: July 7th

Sheraton Santiago
Convention Center

SCL>22-26 OCT / 2017

ADASS XXVII

Astronomical Data Analysis
Software & Systems

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A trabajar!

AURA Observatory in Chile: A platform for current and future U.S. and international astronomical investigation in Chile