NOAO Transformed
David Silva, NOAO Director
NOAO Transformed: **Drivers**
A Mission Unchanged → Enable Discovery

- **You, the Community**
  - NSF AST Portfolio Review (2012)
  - Evolving research topic priorities
  - Evolving research support needs (especially related to Big Data)

- Countdown to LSST era
- NSF programmatic & financial guidance
NOAO Transformed: **Outcomes**
A Mission Unchanged → Enable Discovery

- Base funding reduced → NOAO more lean
- New, deeper partnerships with DOE and NASA
- Open access, PI-class research retained (albeit reduced)
- Increased emphasis on public data from wide-field surveys
- Increased emphasis on data science services
- Path to LSST operations era
- Resultant program is exciting and world-class
NOAO Now
Open access to telescopes
New instruments on all platforms

- Gemini North 8.2-m
- Gemini South 8.2-m
- SOAR 4.2-m
- Blanco 4-m
- Mayall 4-m (until Aug 2017)
- WIYN 3.5-m
- SMARTS 1.5-m, 1.3-m, 0.9-m
- WIYN 0.9-m
Gemini 8.2-m telescopes
Under-used opportunity for USA

USA | 65% of time, over-subscription ~ 2
Excellent image quality
Queue and classical observing
As Mayall access declines, consider Gem-N

Available capabilities

MCAO NIR imager (world-best) (S)
ExAO NIR coronographic (world-best) (S)
→ Imaging and spectroscopy

Optical, multi-mode instruments (N/S)
→ Imaging, long-slit, MOS

NIR spectroscopy (medium & echelle) (N/S)
NIR imager (N)
NIR IFU spectroscopy (N)

NGC 1851, Turri et al. 2016
Arxiv 1509.01764
0.09” PSF K-band
NOAO 4-m Class Telescopes
World-class scientific leadership continues

- Wide-field surveys (small, medium, large)
  - DECam @ Blanco, Mosaic-3 @ Mayall, pODI @ WIYN
  - DESI @ Mayall (coming…)

- Exoplanet mass determination
  - Extreme Precision Doppler Spectrometer (EPDS) (coming…)

- Exoplanet host stellar system characterization
  - General purpose spectrographs @ all 4-m telescopes
  - GLAO imaging @ SOAR

- Time-domain exploration and survey follow up
  - General purpose imagers & spectrographs @ all 4-m telescopes
DECam @ CTIO Blanco 4-m
Dark Energy Camera

3 sq. deg FOV, 520 Mpix
Lifetime (minimum) = 2013 – 2022
Wide-Field Lensing Mass Maps from DES Science Verification Data

Projected mass distribution
Weak lensing (“shear”)
Mass peaks → red
Mass voids → blue
Circles = observed clusters

Only 3% of total DES area

Vikram et al. 2015
arXiv:1504.03002

Major technical triumph: Image size and stability
New dwarf galaxies near Milky Way

Bechtold et al. (2015) (1503.02584)

DECam era

Discovery Timeline: Milky Way Satellite Galaxies

Cumulative Number

Year

NOAO Town Hall, AAS Jan 2016 (D5)
DECam images, 2015 June
Available to you!

NOAO Science Archive
archive.noao.edu
Mosaic-3 @ KPNO Mayall 4-m
DESI, Yale, NOAO collaboration

8K x 8K (64 Mpix) → 36 x 36 arcmin
500 µm thick LBNL deep-depletion CCDs

New CCDs
LBNL 4kx4k

New controllers
LBNL/DESI prototype

Filter 1 µm

NOAO Town Hall, AAS Jan 2016 (D5)
ARCoIRIS @ Blanco 4-m
AKA TripleSpec-4

Long-slit NIR spectrometer
Cross-dispersed (0.8 – 2.5 μm)
Fixed slit format, R ~ 3500
Built by Cornell, funded by NSF
Upgraded → 48 x 40 arcmin
Available filters: $u', g', r', i', z'$
Median image quality: $r' \sim 0.7$ arcsec
On-line pipeline available
Robo-AO @ KPNO 2.1-m

Robotic laser SCAO system
Many objects per night!
FHWM, $r \sim 0.1$ arcsec
*NIR camera coming*…
Caltech/Hawaii team
Public access
Low Mass Planets Cause Slow Stellar Wobble

Sun's Wobble Speed Due to
- Jupiter: 29 mph
- Earth: 0.23 mph

Speed of Desert Animals & EPDS Precision
- Rabbit: 30 mph (1340 cm/s)
- Gila Monster: 1 mph
- Desert Tortoise: 0.2 mph

Mission
Determine masses of Earth-like planets found with (e.g.), K2 and TESS

Requirement: < 50 cm/s
Goal: ~ 10 cm/s

NN-EXPLORE Program
NASA NSF Exoplanet Observational Research

NOAO Town Hall, AAS Jan 2016 (D5)
5000 fibers (~ 700 per sq deg)
0.36 – 0.98 μm @ R ~ 3000
Field-of-view ~ 7.5 sq deg
Much inherited from SDSS/BOSS
Five target classes spanning redshifts $z=0 \rightarrow 3.5$.

~$34$ million redshifts over $14,000$ sq. degrees (baseline survey).

- $2.4$ million QSOs
- $17$ million ELGs
- $4$ million LRGs
- $10$ million brightest galaxies

Image credit: A. Slosar & D. Schlegel, via R. Wechsler
DESI, beyond cosmology

• All data products will be public
  – Targeting survey: images and catalogs
  – Spectra: 33M galaxies + 10M stars

• Public bright time program (2019 – 2023)
  – 500 bright-time hours available for community access
  – Program details under development
  – Watch for Announcement of Opportunity

• Community spectroscopic surveys (2024++)
  – DESI @ Mayall availability not yet guaranteed
  – May require significant non-Federal funding support
  – Decision deferred for several years
Strategic Initiatives
Towards 2020 and beyond

Coming soon…
Observational research infrastructure: To 2030 and beyond

- Cerro Tololo, Cerro Pachón, Kitt Peak
- Viable for decades into the future for Federal & non-Federal facilities
- Objectives
  - Continuous maintenance & modernization
  - Continuous adaptation to new scientific missions (e.g., LSST research support & follow up)

N.B. ~30% of LSST footprint visible from KP above 2 airmass
OIR System Optimization

• 2015 NRC Report recommendations for NOAO
  – Develop / administer new processes for telescope time exchanges
  – Enable community-wide System capability planning
  – Other recommendations also impact NOAO directly and indirectly (e.g., LSST research support services)

• First concrete step
  – Community study on maximizing LSST science return (next slide)

• Next steps
  – Depends on NSF funding, directives
Maximizing Science in the Era of LSST
A Community-based Study

http://www.noao.edu/meetings/lsst-oir-study

• Goal
  – Quantify & prioritize supporting capabilities needed by you for your LSST research (instruments, modes, data tools, etc.)

• Why
  – Influence funding prioritization (public & private)
  – Influence observatory planning (federal and non-federal)

• How You Can Participate (Deadline: 15 Jan 2016)
  1. Describe your LSST-enabled science goals and supporting capabilities you require to achieve those goals
  2. If interested in deeper involvement, volunteer for study group

• Co-sponsored by LSSTPO and NOAO
• Endorsed by NSF, funded by the Kavli Foundation
Premier survey data products

Current projects

- Dark Energy Survey (DES)
  - DECam @ Blanco, 2012 - 2017
  - 5000 sq deg, grizY, r ~ 26
  - Deep fields, r ~ 28
  - Overlaps many VISTA NIR surveys

- DECam Legacy Survey (DECaLS)
  - DECam @ Blanco, 2014 - 2018
  - 9000 sq deg, grz, r ~ 24
  - SDSS/Pan-STARRS overlap, much deeper

- Mayall z-band Legacy Survey (MzLS)
  - Mosaic-3 @ Mayall, 2016 - 2017
  - 5000 sq deg, z, z ~ 23
  - SDSS/Pan-STARRS overlap, much deeper
Data science tools and services
Challenge: mega-object catalogs

- 100s of millions of astronomical objects
- 10s of billions of measurements
- Needed: catalog research support services
Data science tools and services
Solution: NOAO Data Lab

Enable exploration, visualization and analysis
Enable processing at image cutout level
Provide collaborative workspaces

Under development
2016 Jun: AAS demo
2017 Aug: Public release
Data science tools and services
Challenge: time-domain alert flood

• Examples
  – ZTF (2018) → $10^5$ events per night
  – LSST (2023) → $10^7$ events per night

• Solution → ANTARES
  – Arizona-NOAO Temporal Analysis and Response to Event System
  – National service with user plugins in era of LSST
  – Parse events into increasingly narrow bins, concluding with “rarest of rare”
  – Broadcast classifications (“add value”)
  – First public release: 2018
LSST operations and community research support

Strategic objectives

• Major partner within end-to-end LSST system operations
• Center for community research support
  – SLAC = dark energy, NOAO = other
  – Follow up observations → NOAO facilities (North and South)
  – Data science services (Data Lab, ANTARES, etc.)
  – Gateway to Gemini, US federal & non-federal observatories
GSMT operations and community research support

Strategic objectives
- Federal interface = NOAO
- Data operations support
- Community research support
- Instrument consortia participant
- Engage public
NOAO incubated Gemini, LSST, and GSMT (and played major roles in DES/DECam and DESI).

So…

What are the Next Big Questions?
What are the Next Big Projects?
Is there a Next Big Machine?

NOAO looks toward facilitating a community-based discussion.
Enabling discovery today
Working to enable discovery tomorrow