Questions that came up during the talks

- Will LSST rafts survive for 20 years?
- Which, if any, legacy components should we retain? (LSST, DES, DESI…?)
- Can we run optical fiber bundle down through the telescope, or spectrographs up on top end?
- Do we have the power or cooling capacity to run IR or MKIDS sensors?
- We need to know diameter and bend radius of cable wrap constraint
    - HETDEX: ~20k fibers in ~6 cm (extrapolating from 17.8mm IFU bundles)
- What is telecentricity of beam at LSST focal plane? A: rotates 6 degrees at edge
- What is the peak AC power provided at the LSST top end that is available for fiber positioners?
- How much electrical power can we extract?
- What is the sweet spot for the number of fibers? 30,000? BOA case is higher (order of magnitude)
- Have to find the sweet spot between number of fibers and resolution one can get in a reasonable amount of observing time (1 hour? That would give us a redshift S/N~1, good enough for some but not most science cases)
- 50,000 fibers (number is uncertain) would fill the LSST field to measure all available targets with a few hours (t) of integration, in 2000xt hours everything is done, one year of observing would fulfil this program, we would run out of targets pretty quickly
- What is the AR coating performance of the corrector optics in the NIR out to 2 microns? What is the image quality in the NIR? Do we need to redo the corrector (~$15M)

Constraints:

- Need to retain wavefront sensing capability, Gen1 loop runs @ 1/30 Hz
- 3000 kg mass including the corrector
- Length 1.9 m, 1.6m diameter
- Limit on moment of inertia 3500 kg * m2 about x,y and 1000 about z
- Size of cable bundle that can fit through cable wrap
- There is a delta-z requirement in order to preserve image quality: 1mm of defocus gives a donut of 420microns.
- Maximum convective heat load release for the Camera is 200W (This includes the filter exchanger)

Possible Science goals for next-Gen LSST System:

- Get RVs for faint Gaia sources (since Gaia RV spectrograph did not work as well as designed)

    - DESI is doing similar mission (but more northern) - essentially fuse new LSST instrument w/ part of DESI mission?
- Different filter set is easy, affordable
    - One proposal is to implement shifted LSST bandpasses
    - Could also include narrowband filters
    - Some work has already been done re: new filter choices for DES, could leverage that for considering new LSST band
    - Case for narrow band filter choices depends critically on what the science case is; e.g., emission line dominated sources change math vs general use survey
- Fiber-fed spectrograph seems like the optical-spectroscopic way forward, but if people have other non-fiber-fed ideas they are welcome
- Is there an exoplanet science case? If there is, it seems to involve some small number (O(5), how many fibers per spectrograph?) of increased resolution spectrographs at the back end?
- Streams in the galactic disk (kinematics and chemistry; 1000's of them)
- Detection of recent tidal disruptions throughout the entire halo (10-100's)
- 3-D kinematics/chemistry of stars in the Galactic Center (Apogee is doing some of this).
- 10^4 stars in nearby dwarf galaxies with sub-km/s precision kinematics; some of this can be tied to Gaia and in a few cases will reveal *internal* proper motions to for the first time fully map the gravitation potentials/mass distributions in these systems
- Full kinematic/space motion (remember Gaia?) data in nearby clusters, star forming regions
- Chemical sampling of 30+ elements in 10^4 halo stars; will revolutionize many areas, and make 'chemical tagging' work well
- Resolved internal kinematic survey of all accessible open star clusters

MKIDS now is around $10 per pixel, can see a path to $1/pixel. So 100x more expensive as CCDs.

MKIDS- ~3 kW per dilution fridge, but NOT at focal plane.

IR kilonova light curves persist for perhaps a week. Isotropic emission

InGaAs does well out to 1.7 microns, low dark current means operate warmer than HgCdTe
7 deg e-folding of dark current with temperature.

WINTER- 1 deg x 1 deg InGaAs imager on 1 m telescope coming soon.

Need to be careful about fiber choices, emission and transmission in the NIR.

Systematics arise from feeding either pupil image or image plane into fiber.

Could we use the commissioning camera for testing of spectroscopic hardware?

Generic conclusions on fiber-coupling:

- Best to slow down the beam so that f-number emerging from fiber is f/4 or f/5 or so
- This allows us to put pupil image onto fiber tip
- Worry about atmospheric dispersion. We could put linear fiber array along parallactic angle, or have every one be a fiber bundle.

Robotic positioners
“Cobra” dual-twirlers, 10 mm dia patrol radius
DESI shaft and arm, 8mm dia, so 5000 on focal plane, brushless gear motors, hard to scale
AAO has tilting spines, FMOS and 4MOST and MSE like these. 2 min config time. ~10 mm dia
StarBugs put positioner on glass plate, 10mm dia

Chief ray rotation for LSST is 6 deg*(R/R_max)

All of the modern approaches require a camera to image the fiber ends with them being back-illuminated. We would need to put this in the central hole of the primary.

Typically 2-7 iterations, takes between 45 sec and 2 minutes.

Peak power is 2W per pos.
1 Joule per positioning step

Guesstimate is 1K$ per positioner plus cost of fiber, connections. May add up to 5 to 10k including spectrographs (DESI full cost is ~50M?) for 5000 positioners.

Possible working groups-

1) What is the science case for spectroscopy on LSST, and is it competitive/useful?
2) What are the realistic prospects for imaging sensors (Ge, InGaAs…)?
3) Conceptual design alternatives for spectrographs.

Tasks-

Demonstrate a fiber-coupling optical scheme and test beam transport properties
Evaluate fiber positioner options in the context of SWAP constraints
Sketch out illustrative science case?

Target density: ~10 per square arc min to r=24 AB. That’s 3600 square arcsec so density is 10/3600=> 360 square arcsec per object. Typical separation is 20 arcsec. That’s 1mm of spatial separation. At 14 per square arcmin we get 1B objects in 20K square degrees. Drop one magnitude get 0.4 times that, at r=23.

Using lenslets to reimage pupil onto fiber tip has two advantages- immune to pointing errors, and also good fill factor.

About 20K fibers in the focal plane seems a good balance point.

Jeff Newman on next-gen spectro

Facilities in N go down to -20 declination, 60% of LSST footprint
Actual projects:

- DESI is 5000 fibers, 7 sq deg, R of 2000 in blue and 5000 in red, dedicated obs plan

Start is spring 2020, lat +32
360 to 980 nm
Red resolution is enough to work between sky lines

- William Herschel Telescope, WEAVE, La Palma

2 deg FOV
4.2m
+28N
960 fibers
1 hour reconfig time (but two field plates, so can reconfigure one whilst observing with the other, and actual overhead is therefore low)
R~5000 or 20000
Spring 2020

- legPFS

8m at +20 latitude
2400 fibers over 1.3 deg
Out to 1.26 microns
Resolution of 4300 in red
300 night survey planned to start 2021 but time is shared w other projects on telescope

Potential projects:

- DESI-S:

Few M$ for move, 75M$ to replicate DESI. Could use existing corrector for 3 sq deg.

- Magellan.

f/3 secondary would match DESI input beam, can use their fiber positioners
Can fit around 3000 fibers
Guess is 75M$ for instrument. PFS was comparable

Some talk of a new facility with 20000 fibers with 4 sq deg. Magellan-like aperture.
Around 75M$ replication cost for telescope. Total cost around 150M$

- Keck

10m proposed spectrograph with 1800 fibers, R~3500, 20 arcmin field. Survey efficiency as good as PFS. CCD wavelength range

- GMT

25m, has uniquely large field, 20 arcmin. 1000 fibers perhaps ten 1000-fiber IFUs.
GMACS has fiber-input with R of 6000-8000.

- LSST options
- 1. 3800 DESI-like positioners
- 2. 35K fibers, 1 per square arcmin
- 3. 500K fiber positioners

- MSE
  See arXiv paper, 1.8 sq deg, medium R~3000

Jeff says we get 5 hours exposure time for 20K square degree in ten years with 500k positioners. 1 billion spectra
Q: what resolution? At least 4000 in red to split O2 doublet. SNR better than Deep2, which is SNR~1 per angstrom at R=6000. DESI is 20 min exposure on 4m at r=23.5. That gives ~85% redshift success rate at SNR=1.5 or 2 per angstrom.

See arXiv 1610.01661 for Kavli report on spectroscopy matched to LSST. cost estimate was $1K per square meter of aperture per night. Assuming all instruments are equivalent, for medium-resolution multiobject spectroscopy:

Photoz training set
100 hours integration on ten meter. Wants 30K galaxies.

SN hosts
100 new Ia per sq deg per year. So ten per square degree are bright at any given time. Sparse.
Get best 50K SNe

Halo streams and local dwarf galaxies
Dispersions for r<300 kpc objects
3200 hours on 8 m

MW halo survey
125 g<23 stars per sq deg over entire LSST footprint.
2.5 hours per 8 m pointing

Gal evolution survey
120K galaxies $0.5 < z < 2$
18 hours per pointing on 4m

Get Table from Jeff's talk .

One good application-
Deep 30-band narrowband imaging for ten years on 2000 sq deg, can be photoz training set.
Get 0.001(1+z) photoz errors. BAO and RSD LSS too.

Redshift errors scaling from DEEP2, get similar number

Four-MOST.
70% to ten surveys, mostly Galactic structure, running in parallel.
4.2 sq deg, 2436 fibers, R of 5000 and 20000, fed by 800 fibers. But three narrow wavelength windows. Twenty min exposures, 75M spectra
On VISTA telescope, has an ADC

Patrol area is 2.4 times pitch. High-res and low-res fibers are interleaved, feed two different kinds of spectrographs. Need R>18000 for chemical archeology

They use 6K x 6K E2V sensors. Nine sensors. So ~360Mpix.
Five year survey, layered exposure times of 2, 10, 20 and 30 min.
Total integration time varies from 1 to 10 hr
Faintest targets are around 22.5 AB

2022-2027 running of survey.

This project will likely skim the cream for Galactic structure spectroscopic followup, so the question is what's the marginal gain to go fainter/more?