# WBS 6.1.2
# Pixel Services

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U.S. ATLAS HL-LHC Upgrade Director's Review of NSF/DOE Scope
Brookhaven National Laboratory
Upton, New York
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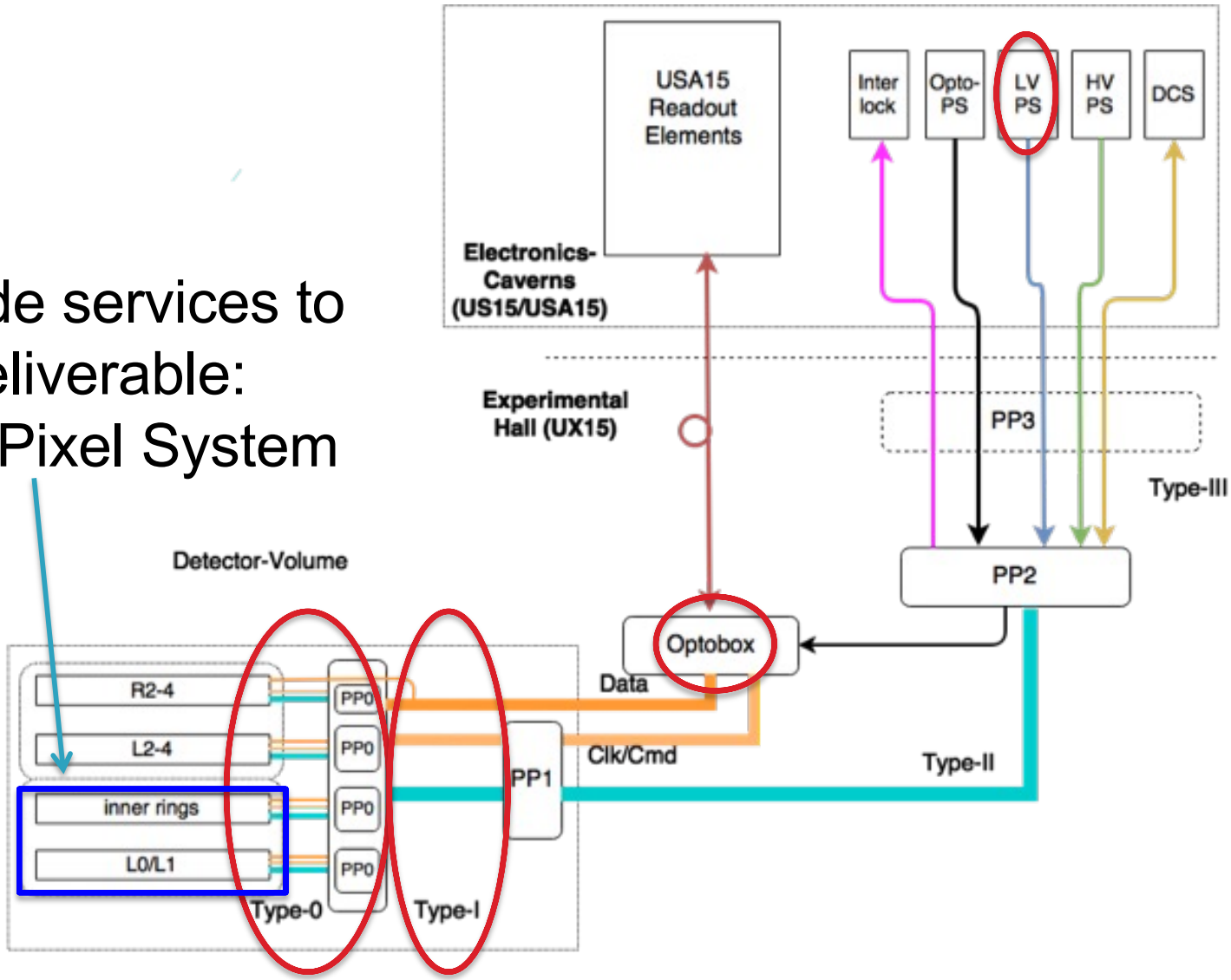
# Outline

- Technical Details
  - Deliverable Overview
  - R&D Status and Plans
- Project Management
  - Management Structure: CAM and Ics
  - Basis of Estimate
- Cost and Schedule
  - Budget and Schedule estimates
  - Risk and Uncertainty
- Closing Remarks

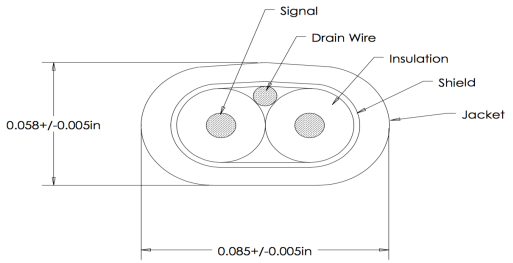

# Technical Details

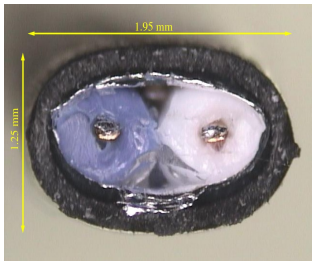
# Deliverable Overview

Provide services to US deliverable: Inner Pixel System



# WBS 6.1.2.1




- Institution: SLAC
- 6.1.2.1.1: TwinAx
  - Twin co-axial cables
  - Challenge: high-speed data transmission up to 5.5 m of skinny cables with acceptable attenuation
- 6.1.2.1.2: PP0
  - Design/prototype/production of PP0 with connectors for data, CMD/ CLK, LV, HV, DCS (safety monitors)
  - challenge: minimum material and insertion loss in bandwidth/signal strength
- Technical Specs (see later)

# WBS 6.1.2.2

- Institution: Ohio State
- 6.1.2.2: Opto-board
  - design/prototype/production of optical modules (opto-boards), including driver/receiver ASICs
  - Challenge: equalization and pre-emphasis of degraded signal after 5.5 m of skinny cable to drive a VCSEL at high-speed
- Technical Specs (see later)

| | Inner Pixel | | Pixel System | |
|---|---|---|---|---|
| | Driver | Receiver | Driver | Receiver |
| Opto-boards needed | 326 | 22 | 1,528 | 108 |
| Including spares | 391 | 26 | 1,833 | 129 |
| Yield (%) | 80 | 80 | 80 | 80 |
| Material ordered | 469 | 31 | 2,200 | 155 |

# WBS 6.1.2.3

- Institution: Oklahoma State
- 6.1.2.3.1: Power Supply
  - design/prototype/production of power supplies, backplane, control system, chassis
  - Challenge: supply constant current up to 16 FE ASICs in series
  - Technical Specs: supplies of constant current of 8 A per channel to the front-end chips with a voltage range of 1.2-1.5 V per chip

| | Inner Pixel System | Pixel System |
|---|---|---|
| Number of modules needed | 11716 | 2456 |
| Number of modules per one power supply | **8** | **8** |
| Production yield | **90%** | **90%** |
| Additional spares | **11%** | **11%** |
| Power Supply Channels per Crate | 10 | 10 |
| Total number of power supplies to be produced | **1806** (= 2456/8/0.9*1.11) | **380** (= 2456/8/0.9*1.11) |
| Total cost of Inner System power supply production | $903,000 | $190,000 |

# WBS 6.1.2.3

- Institution: Oklahoma State
- 6.1.2.3.2: Flex Circuit
  - design/prototype/production of flex circuits for transmission of CMD/CLK, LV, HV, DCS
  - Challenge: high-speed transmission/low signal or voltage drop with minimum material
  - Technical Specs (see later)

| | Production | Pre-Production |
|---|---|---|
| **Rings needed for inner system** | 300 | |
| **Yield** | 80% | |
| **Spares** | 20% | |
| **Flexes to be produced** | 420 | 30 |
| **Total material cost** | $278,000 | $52,000 |

# WBS 6.1.2.4

- Institution: UCSC
- 6.1.2.4: Type-1 bundle
  - design/prototype/production of cable bundles for data, CMD/CLK, LV, HV, DCS
  - Challenge: compact bundles with connectorization of minimum loss
  - Technical Specs (see later)

# Technical Specs

- 6.1.3.1 (Type-0 Services), 6.1.3.2 (Patch Panel 0), 6.1.3.3 (Twinax Cables), 6.1.3.4 (Type-1 Services) and 6.1.3.7 (Equalizer): radiation-hard data transmission from the modules to the optical converters at 5.12 Gb/s up to 5.5 meters with maximum attenuation of 20 dB.
- 6.1.3.5 (Opto-Links): optical converters for converting electrical data signals to optical signals for transmission to the DAQ system at 5.12 Gb/s per channel and vice verse for the clock/command signal at 160 Mb/s from the DAQ system.
- 6.1.3.6 (Serial Powering): Serial power supplies produce a constant current up to 8 A per serial power chain and provide a voltage of 1.5-2 V per module, with a maximum of 16 modules per chain.

# R&D

- 6.1.2.1:
  - TwinAx: cables of different dielectric material and gauges prototyped. Currently evaluating a possible final prototype cable.
  - PP0: R&D just started. Production in FY20.
- 6.1.2.2:
  - Opto-boards: R&D just started. Previous R&D funded via CDRD. Decision on 12-channel opto-boards vs “4+1”-channel opto-module of Versatile Link+ project in FY19.
- 6.1.2.3:
  - Serial Powering with several FE-I4 chips currently being tested. Production in FY22.
  - R&D on flex circuit just started. Production in FY20.
- 6.1.2.4:
  - R&D on Type-1 cable bundle just started. Production in FY20.

# Project Management

# L3 Project: Effort

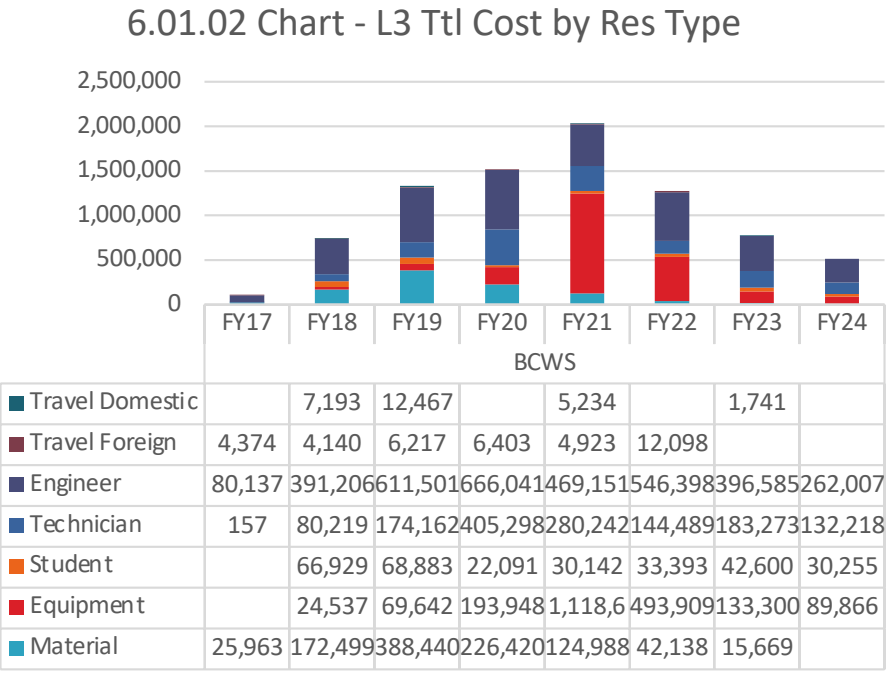
- 6.1.2.1: TwinAx/PP0
  - SLAC: Su Dong leads the effort with contributions from physicists plus engineers and technicians available at cost.
  - TwinAX cost estimate based on several years of R&D and PP0 based on fabricating similar objects for Insertable Barrel Layer (IBL) of ATLAS Pixel detector
- 6.1.2.2: Opto-board
  - Ohio State: K.K. Gan leads the effort with contributions from physicists plus engineers and technicians at cost.
  - Cost estimate based on building two generations of opto-boards for the Pixel detector of ATLAS

# L3 Project: Effort

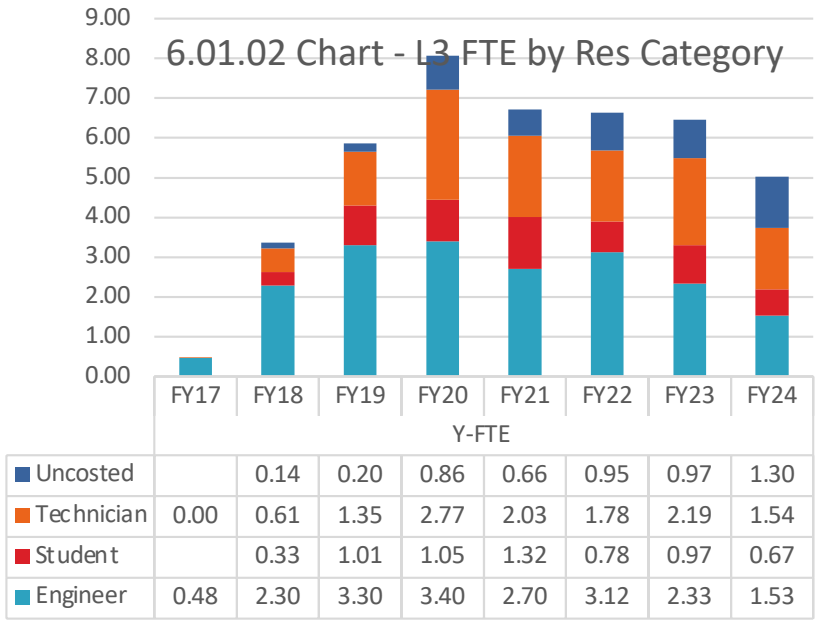
- 6.1.2.3: Power supply and flex circuit
  - Oklahoma State: F. Rizatdinova leads the effort with S. Welch as the lead engineer at cost.
  - cost estimate mostly based on quotes and data from previous hardware development projects
- 6.1.2.4: Type-1 bundle
  - UCSC: J. Nielson leads the effort with contributions from physicists plus engineers and technicians at cost.
  - cost estimate based on similar objects for Insertable Barrel Layer (IBL) of ATLAS Pixel detector


# Cost and Schedule

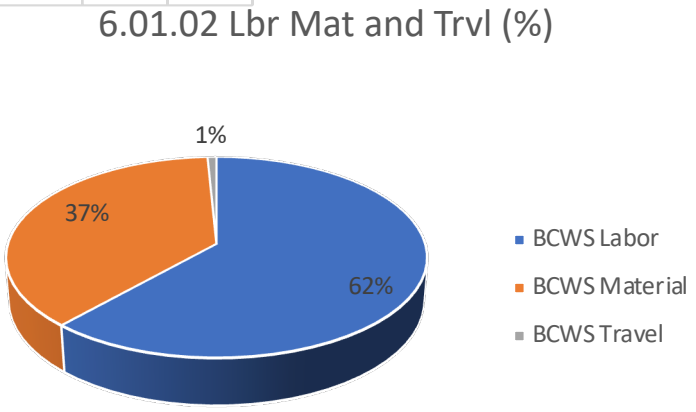
# Budget & Effort




| | FY17 | FY18 | FY19 | FY20 | FY21 | FY22 | FY23 | FY24 |
|---|---|---|---|---|---|---|---|---|
| Travel Domestic | | 7,193 | 12,467 | | 5,234 | | 1,741 | |
| Travel Foreign | 4,374 | 4,140 | 6,217 | 6,403 | 4,923 | 12,098 | | |
| Engineer | 80,137 | 391,206 | 611,501 | 666,041 | 469,151 | 546,398 | 396,585 | 262,007 |
| Technician | 157 | 80,219 | 174,162 | 405,298 | 280,242 | 144,489 | 183,273 | 132,218 |
| Student | | 66,929 | 68,883 | 22,091 | 30,142 | 33,393 | 42,600 | 30,255 |
| Equipment | | 24,537 | 69,642 | 193,948 | 1,118,6 | 493,909 | 133,300 | 89,866 |
| Material | 25,963 | 172,499 | 388,440 | 226,420 | 124,988 | 42,138 | 15,669 | |




| | FY17 | FY18 | FY19 | FY20 | FY21 | FY22 | FY23 | FY24 |
|---|---|---|---|---|---|---|---|---|
| Uncosted | | 0.14 | 0.20 | 0.86 | 0.66 | 0.95 | 0.97 | 1.30 |
| Technician | 0.00 | 0.61 | 1.35 | 2.77 | 2.03 | 1.78 | 2.19 | 1.54 |
| Student | | 0.33 | 1.01 | 1.05 | 1.32 | 0.78 | 0.97 | 0.67 |
| Engineer | 0.48 | 2.30 | 3.30 | 3.40 | 2.70 | 3.12 | 2.33 | 1.53 |

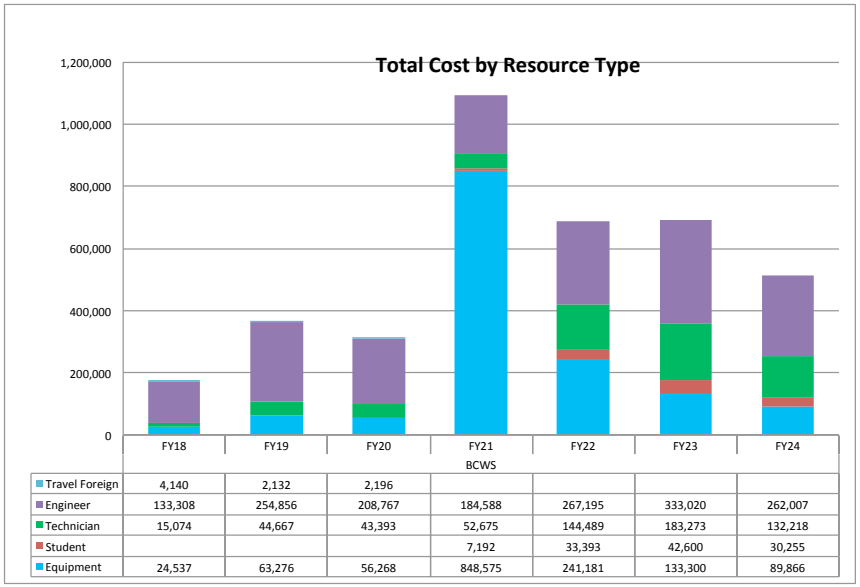


# Budget & Effort

**WBS 6.01.02 Pixel Services**

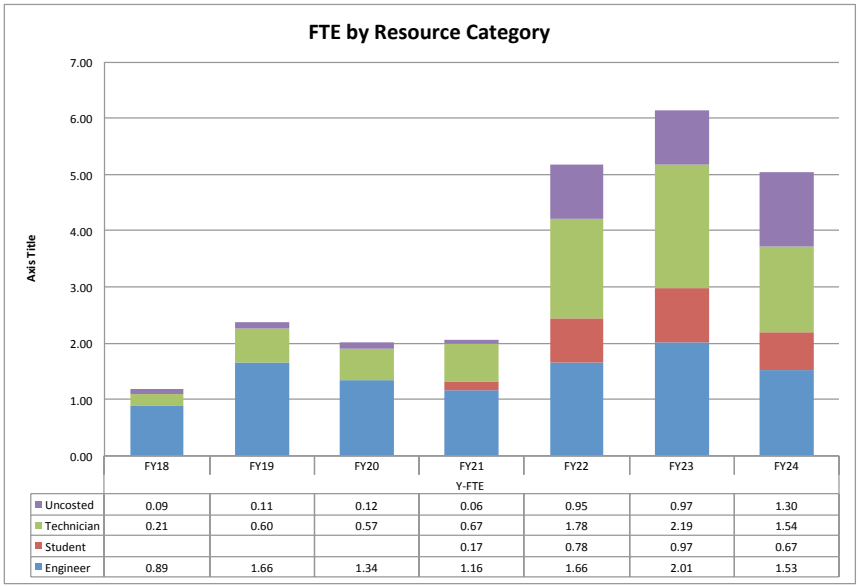
| | FY17 | FY18 | FY19 | FY20 | FY21 | FY22 | FY23 | FY24 | Grand Total |
|---|---|---|---|---|---|---|---|---|---|
| 6.01.02.01.01 / SLAC Twinax-Inner Section SLAC | 4,104 | 88,312 | 257,522 | 5,503 | | | | | 355,441 |
| 6.01.02.01.02 / SLAC PP0-Inner Section SLAC | 4,716 | 55,890 | 192,728 | 276,874 | | | | | 530,209 |
| 6.01.02.02 / OSU Optical Links_OSU | | 177,058 | 364,931 | 310,624 | 1,093,030 | 686,260 | 692,193 | 514,346 | 3,838,442 |
| 6.01.02.03.01 / OKS Serial Powering OkS | 101,811 | 277,405 | 225,787 | 117,861 | 329,107 | 586,167 | 80,975 | | 1,719,114 |
| 6.01.02.03.02 / OKS Inner Stave Flex OkS | | 97,343 | 150,678 | 383,936 | 383,671 | | | | 1,015,627 |
| 6.01.02.04 / UCSC Type-I Services | | 50,714 | 139,665 | 425,403 | 227,567 | | | | 843,350 |
| **Grand Total** | **110,631** | **746,722** | **1,331,312** | **1,520,201** | **2,033,375** | **1,272,427** | **773,168** | **514,346** | **8,302,182** |

# 6.1.2.2 Budget & Effort: Opto-Board



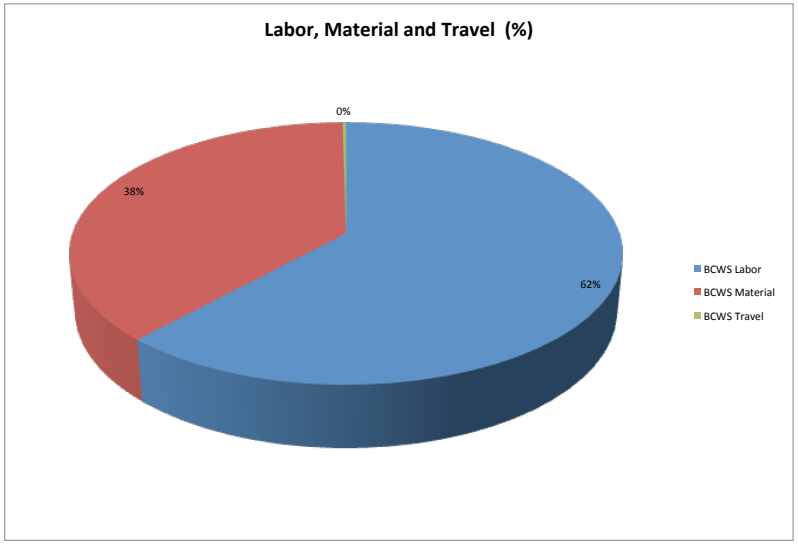

BCWS

| | FY18 | FY19 | FY20 | FY21 | FY22 | FY23 | FY24 |
|---|---|---|---|---|---|---|---|
| Travel Foreign | 4,140 | 2,132 | 2,196 | | | | |
| Engineer | 133,308 | 254,856 | 208,767 | 184,588 | 267,195 | 333,020 | 262,007 |
| Technician | 15,074 | 44,667 | 43,393 | 52,675 | 144,489 | 183,273 | 132,218 |
| Student | | | | 7,192 | 33,393 | 42,600 | 30,255 |
| Equipment | 24,537 | 63,276 | 56,268 | 848,575 | 241,181 | 133,300 | 89,866 |




Y-FTE

| | FY18 | FY19 | FY20 | FY21 | FY22 | FY23 | FY24 |
|---|---|---|---|---|---|---|---|
| Uncosted | 0.09 | 0.11 | 0.12 | 0.06 | 0.95 | 0.97 | 1.30 |
| Technician | 0.21 | 0.60 | 0.57 | 0.67 | 1.78 | 2.19 | 1.54 |
| Student | | | | 0.17 | 0.78 | 0.97 | 0.67 |
| Engineer | 0.89 | 1.66 | 1.34 | 1.16 | 1.66 | 2.01 | 1.53 |



# Schedule

- Items needed at SLAC integration in 2022:
  - 6.1.2.1: TwinAx/PP0
  - 6.1.2.3.2: flex circuits
  - 6.1.2.4: Type-1 bundles
- Items needed at CERN in 2024:
  - 6.1.2.2: opto-boards
  - 6.1.2.3.1: serial power supplies
- Main external dependencies:
  - System test: FE ASIC (RD53) + cables + opto-board for operation at 5.12 Gb/s

# Risk and Uncertainty

- RD-06-01-02-001:
  - 5.12 Gb/s data transmission not achievable at 5.5 m
  - Mitigation: allocate more resource in connectorization
  - Responses: use slightly larger cables
- RD-06-01-02-002:
  - Opto links not ready
  - Mitigation: allocate three prototype cycles instead of the standard two in the ASIC development
  - Responses: allocate one more prototype cycle in the ASIC development
- RD-06-01-02-003:
  - Serial powering fails to meet specifications
  - Mitigation: More protoyping of power supply and study of the cooling requirement
  - Responses: Allocate more resource for prototyping and use new cables instead of the existing cables.

# Milestones

- FY19: TwinAx FDR + PRR
- FY19: Type-1 bundle FDR
- FY19: Flex FDR
- FY19: PP0 FDR
- FY20: PP0 PRR
- FY20: Opto-board PDR
- FY20: Power supply FDR
- FY20: Type-1 bundle PRR
- FY20: Flex PRR
- FY21: Opto-board FDR + PRR
- FY23: power supply PRR

# Closing Remarks

- Services WBS contains both active and passive deliverables
- Some R&D are well advanced and others just started
- Main technical challenge:
  - Achieve 5.12 Gb/s data transmission at up to 5.5 m of cables plus connectors with less then 20 dB of attenuation

# BACKUP

# Bio Sketch of L3 Manager

- K.K. Gan, Professor of Physics, The Ohio State University
- Member of ATLAS since 1998
- Leading the design and fabrication of two generations of optical links for the ATLAS pixel detector

# Institute Capabilities

- 6.1.2.1, SLAC:
  - Large facility for electronics development and fabrication
  - Large pool of engineers and technician available at cost
  - Previously involved in the Insertable B-Layer pixel project
- 6.1.2.2, Ohio State:
  - Clean room with automatic wire bonders and probe stations etc
  - Two engineers available at cost
  - Previously leading two ATLAS pixel opto-link projects
- 6.1.2.3, Oklahoma State:
  - Good facility for electronics development and fabrication
  - One  engineer available at cost
  - Previously involved in the Insertable B-Layer pixel project
- 6.1.2.3, UCSC:
  - Good facility for electronics development and fabrication
  - Pool of engineers and technician available at cost
  - Previously involved in the Insertable B-Layer pixel project