Power System Control (PSC) and Telecommunications

Sustain Program

Asset Management Strategy

Laura Demory, Program Manager

March 2012

Executive Summary

- Equipment Covered
  - VHF
  - Telecom Transport
  - Telecom Support Equipment
  - SCADA/Telemetry/Supervisory Control
  - Field Information Network (FIN)/Operational Networks
  - Telephone Systems
  - System Telecommunications/Fiber Optic Cable

- Key Drivers
  - Multiple generations of equipment on the BPA system and resulting technology interoperability and obsolescence issues
  - Equipment condition and lack of manufacturer support
  - Rapid evolution of technologies in the market place
  - Evolving power system operations/needs
  - Evolving regulatory requirements
  - Constraints on outage and resource availability

Executive Summary

- Changes since last IPR
  - Completed development of PSC/Telecom strategy
  - Worked with consultant on development of a Planning Tool to evaluate economic impact of implementation choices over a 30-year planning horizon
  - Produced an implementation plan prioritized based on impact to Total Economic Cost and potential outage risk and impact
- Key strategy tasks for next 10 years
  - Implement process improvements in Documentation, Training, and Testing
  - Complete analog to digital migration
  - Overcome backlog of equipment replacements and reach a steady state replacement based on best economic lifecycle
- Key implementation Tasks
  - Implementation Project Manager in place
  - Complete hiring of documentation contractors – February 2012
  - Complete hiring of Test Group Team Lead – spring 2012
  - Launch Technology Council – spring 2012
  - Identify space changes and equipment needs for Training initiative – ongoing
  - Detailed equipment replacement and upgrade plans – ongoing

Budget Forecasts

Thousand's $	SOY	OMB								
	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021
Capital Cost Forecast										
System Replacements										
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TRANSPORT	1,295	1,179	1,143	1,140	1,140	1,045	1,181	1,195	1,209	1,208
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Note: Expense forecasts prior to completion of the Asset Strategy project yearly increasing budget needs. As the strategy is implemented, early years require startup costs for process improvement initiatives then maintenance requirements decrease as old equipment is retired, and process improvements begin to provide labor savings that is reflected in out-year expense budget projections.

What equipment is covered?

What is the health of the assets, and what risks must be managed?

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What costs and resources will be needed?

Program Accomplishments FY10 – FY11

PSC Equipment Covered

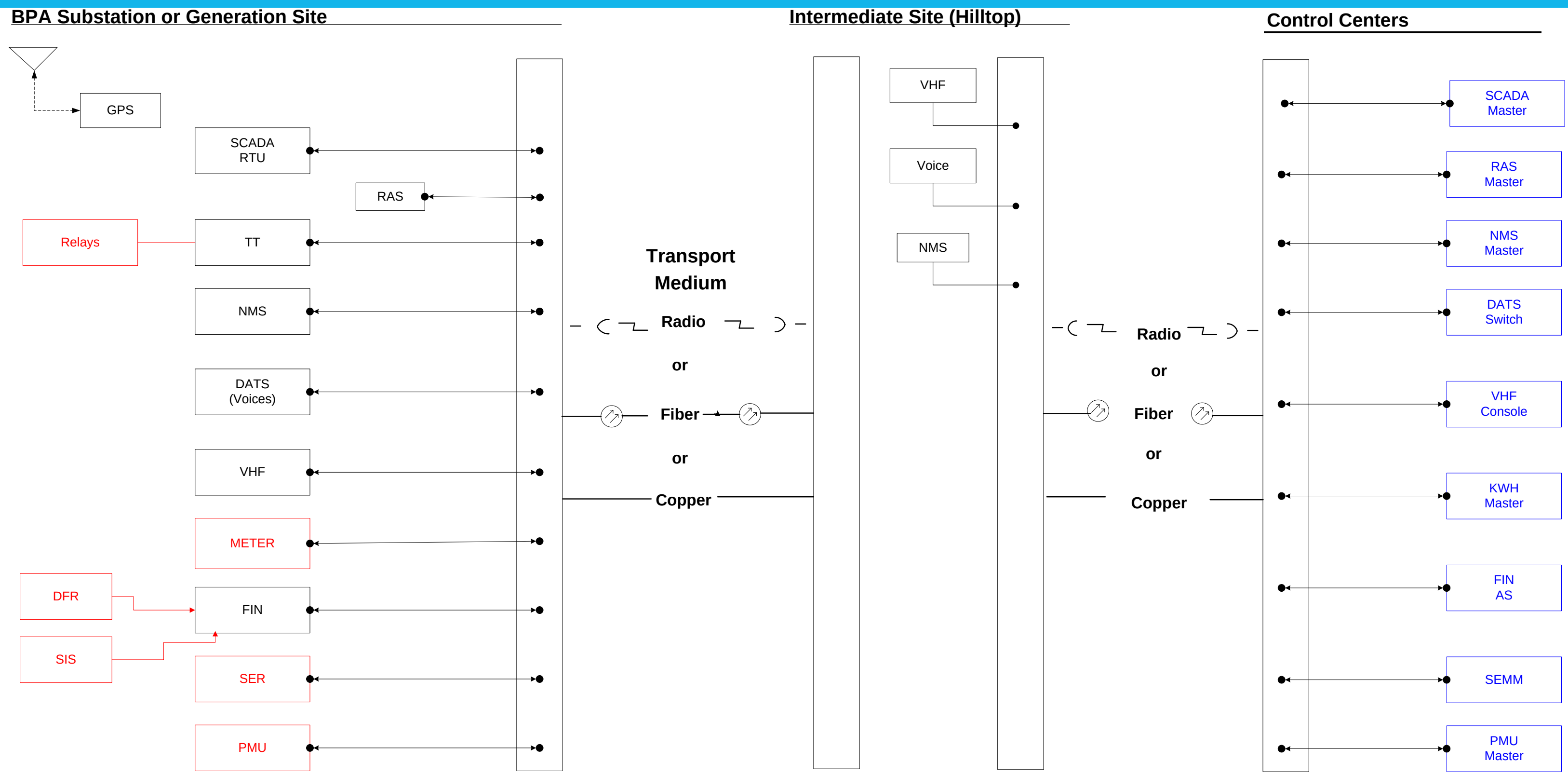
Power system control and telecommunications equipment at a total of 732 sites, including 111 radio sites, 482 BPA and customer-owned substations, and 139 other sites such as power houses, maintenance buildings, and control centers.

For capital accounting purposes, equipment is grouped into seven, level-5 nodes:

- VHF - this equipment includes all VHF fixed repeaters and controller units, mobile radios, and portable handheld radio units.
- Telecom Transport - this equipment includes analog and digital microwave radio, analog and digital multiplex, fiber optic terminal equipment and UHF radios. The combination of these systems creates an extensive, system-wide communications network, with over 10,000 telecom circuits (primarily data and control circuits)
- Telecom Support Equipment - this equipment includes alarm systems, batteries/chargers, DC-DC converters, engine generators, UPS systems, timing systems, fault locators, miscellaneous support systems, and towers and grounds
- SCADA/Telemetry/Supervisory Control – this equipment includes Supervisory Control And Data Acquisition Remote Terminal Units (RTUs), supervisory control systems, and telemetering systems
- Field Information Network (FIN)/Operational Networks – data networks for data transfer. This equipment includes FIN network equipment, operational network equipment, network management system equipment, and modems
- Transfer trip – this equipment includes protection units and Remedial Action Scheme (RAS) communication units
- Telephone Systems - BPA maintains an extensive internal Dial Automatic Telephone System (DATS) for daily operation and maintenance activities. This equipment includes DATS switches and supporting systems, key system and telephone equipment, teleprotection systems
- Fiber Optic Cable – this category includes approximately 3,000 miles of fiber optic cable

(# units of equipment shown in parenthesis)

Equipment Covered (2)



LEGEND

PSC and Telecom items

SPC Items

Control Center Area

AS	ACCESS SERVER
DATS	DIAL AUTOMATIC TELEPHONE SYSTEM
DFR	DIGITAL FAULT RECORDER
FIN	FIELD INTRANET
GPS	GLOBAL POSITIONING SYSTEM
KWH	KILOWATT HOURS
NMS	NETWORK MANAGEMENT SYSTEM
PMU	PHASOR MEASUREMENT UNIT
RAS	REMEDIAL ACTION SCHEME
RTU	REMOTE TERMINAL UNIT
SCADA	SUPERVISORY CONTROL AND DATA ACQUISITION
SEMM	SEQUENTIAL EVENTS MONITOR MASTER
SER	SEQUENTIAL EVENTS RECORDER
SIS	SUBSTATION INFORMATION SYSTEM
TMR	TELEMETER RECEIVER
TMX	TELEMETER TRANSMITTER
TP	TELEPHONE PROTECTION
TT	TRANSFER TRIP
VHF	VHF RADIO

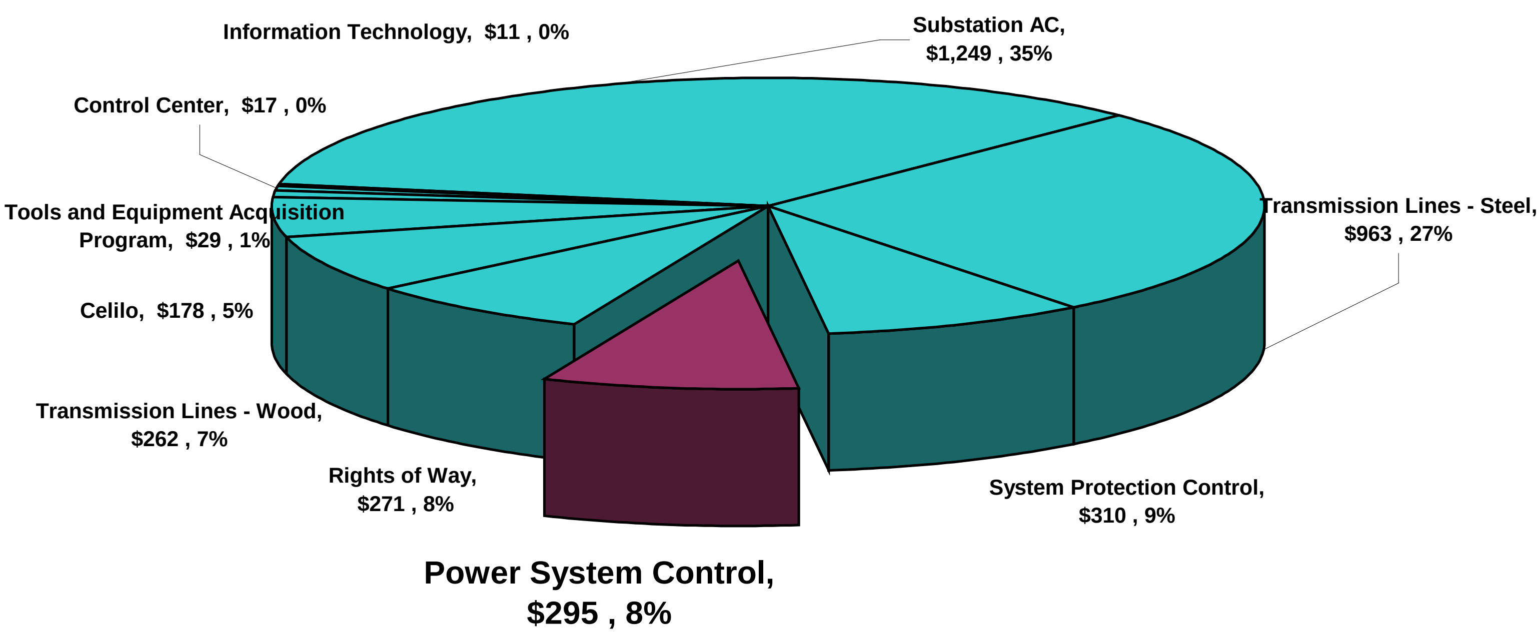
NOTES:

1. All circuits are bi-directional
2. Interconnected generation sites can contain some or all equipment types found at BPA Substations

Net Plant in Service

(in Millions $)

Transmission Sustain Programs
Historical Investment After Depreciation
as of Sept. 30, 2011
(in millions)
Total Book Value is $ 3,585 million



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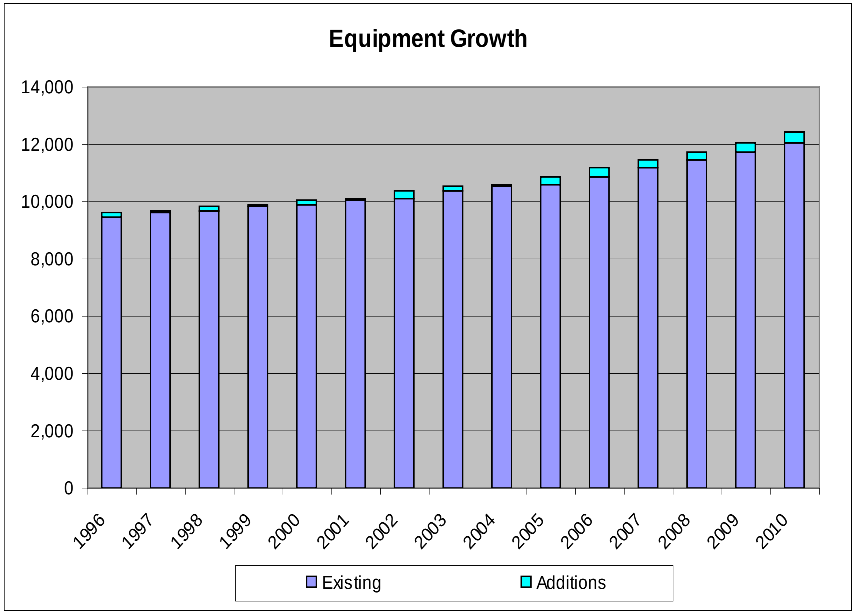
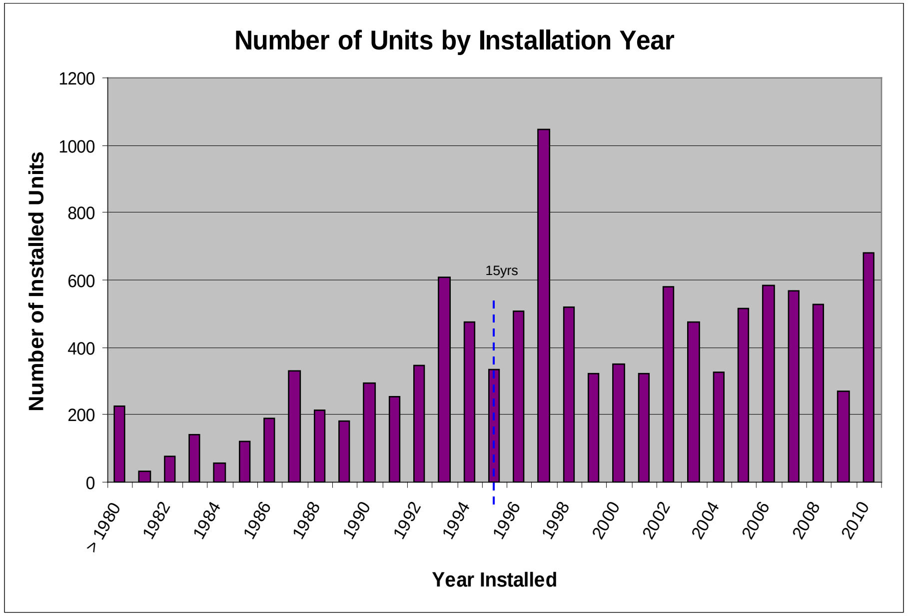
Program Accomplishments FY10 – FY11

PSC Equipment Count & Demographics

Since 1995, PSC/Telecom equipment count has gone from approximately 9,600 to 12,500, an increase of almost 30% in a 15-year period.

Much of this equipment has not been replaced, and around 45% of installed equipment is beyond its average expected life. Large backlogs of replacements need to be addressed.





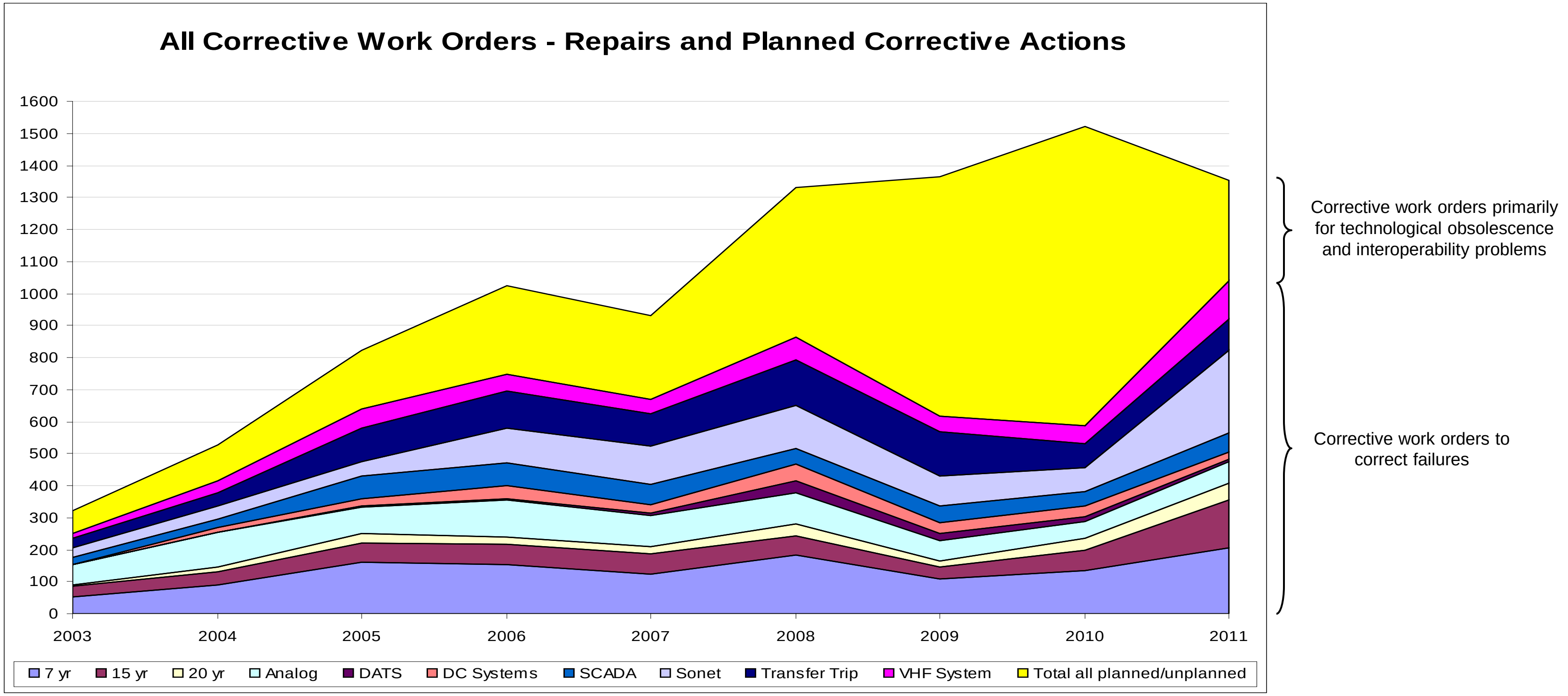
Lifecycle Assumptions by Equipment Type

- Lifecycle for PSC equipment is typically 8 to 25 years depending on the equipment type
- Majority of equipment falls in the 10 to 15 year range, and then should be replaced
- About 45% of our existing PSC equipment is beyond its expected service life
- The lifecycles at right were used in this strategy

EQUIPMENT TYPE	Lifecycle (Yrs)	Number of Units	Average Age
SCADA	13	212	15
Transfer Trip	12	846	14
RAS	14	666	15
Fiber Cable	25	3000 miles	
Mobile	15	1480	13
VHF Repeater	12	65	19
7 Year Lifecycle (Comm Alarm Systems, VRLA Batteries)	9	715	9
20 Yr Batteries (Flooded Cell Batteries)	22	248	11
DC Power 15 (Chargers, DC-DC Converters)	18	546	13
Misc 10 Year (Fiber Patch Panels; Fiber Drivers, etc.)	12	422	10
UHF Radios	11	109	11
Telemetering	18	578	12
Telephone (Key Systems, etc.)	12	720	17
Engine Generators	22	80	20
SONET Other (Fiber nodes)	12	261	8
DATS	12	14	7
SONET Ancillary (digital multiplex, digital microwave)	10	635	7

The number of corrective actions has increased dramatically over the last eight years

- Equipment failures are tracked via the number of corrective work orders that have been created for unplanned work
- System operations and economic impacts can be large if certain types of equipment -- such as Transfer Trip, SCADA, SONET, and RAS equipment -- fail
- A growing share of corrective work orders are to mitigate technological obsolescence and interoperability problems



Principal risk to be managed is Technological Obsolescence

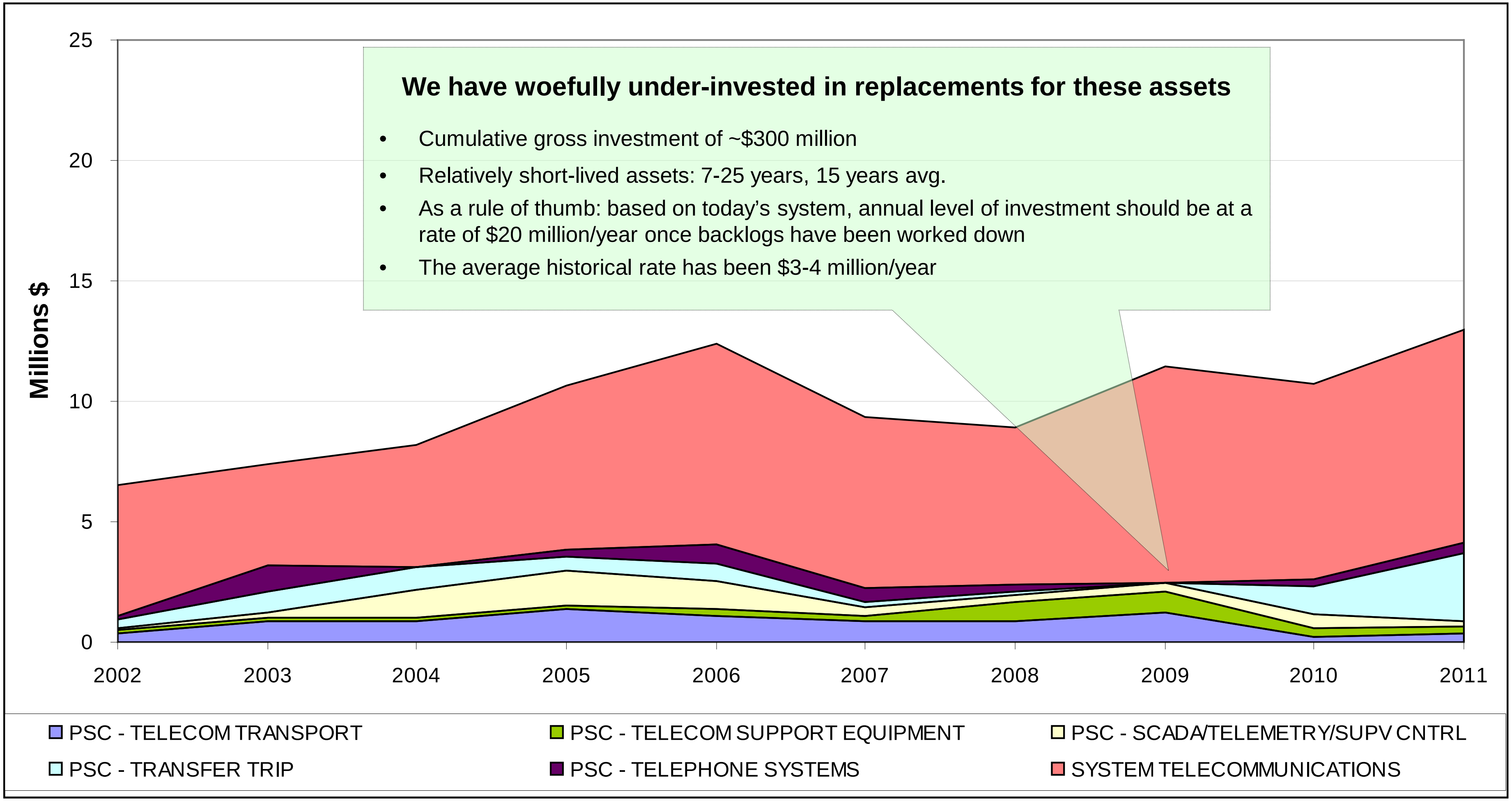
- **Multiple generations of equipment on the BPA system**
- **Rapid evolution of technologies in the market place**
- **Evolving power system operations/needs**
- **Evolving regulatory requirements**
- **Constraints on outage and resource availability**

Leading to . . .

- **Serious, increasing risks of equipment failure**
  - **Older vintage equipment often without vendor support and spare parts**
- **Interoperability problems across equipment vintages**
  - **Unnecessary derate/outage and other risks**
- **Complicated, time consuming maintenance and repair leading to backlogs and higher costs**
- **An excessively large and expansive spare parts inventory**
- **Skills deficits and long training periods**

Technological obsolescence risk is distinct from failure risk. Obsolescence risk can affect equipment maintainability, interoperability, and the duration of a curtailment/outage should a failure occur. Equipment may be in healthy physical condition, but technologically obsolete. Conversely, equipment may be in poor physical condition, but technologically up to date.

PSC Capital Expenditure History

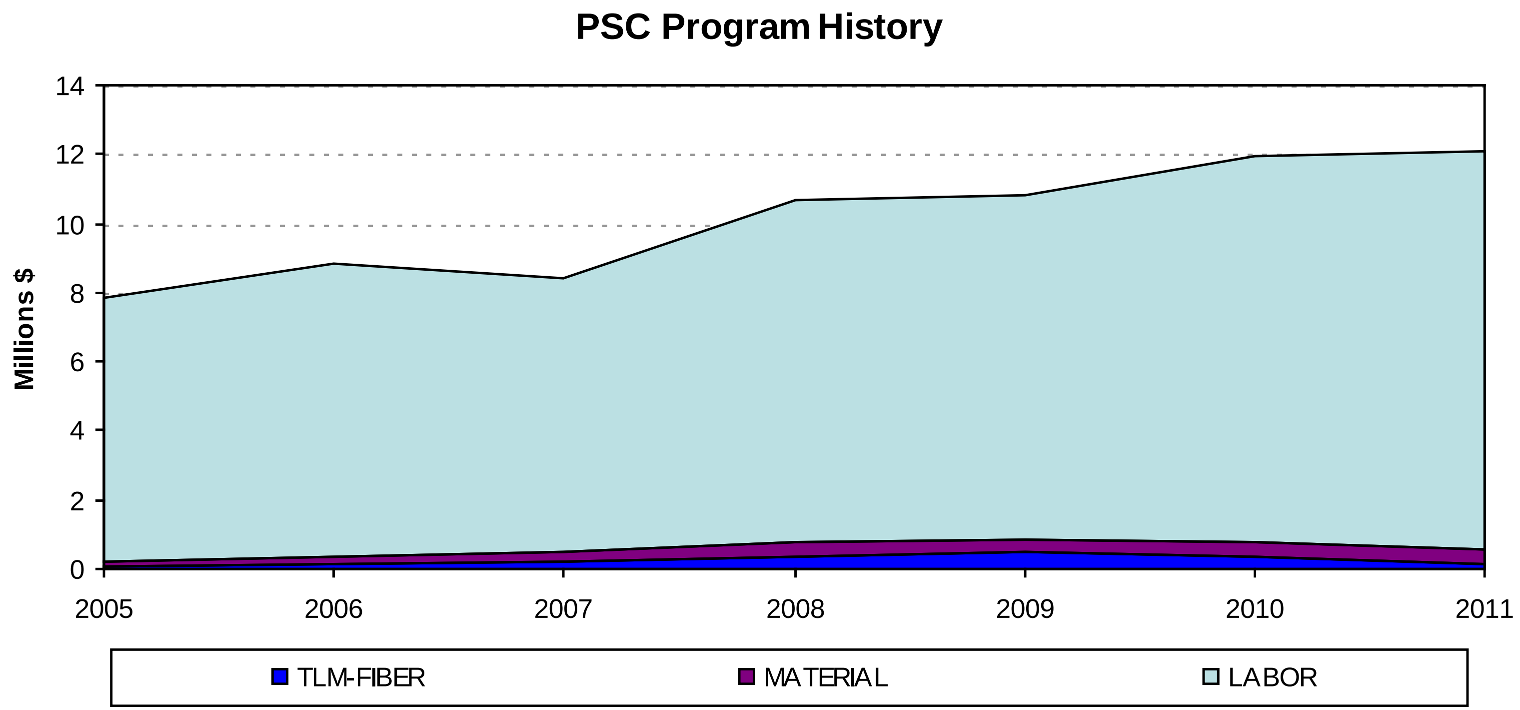


We have woefully under-invested in replacements for these assets

- Cumulative gross investment of ~$300 million
- Relatively short-lived assets: 7-25 years, 15 years avg.
- As a rule of thumb: based on today's system, annual level of investment should be at a rate of $20 million/year once backlogs have been worked down
- The average historical rate has been $3-4 million/year

PSC Maintenance Expense History

These assets require a significant level of resources to maintain, repair and operate. Maintenance expenses in FY 2012 will total approximately $15.8 million. These expenses are expected to continue to grow as the system gets larger and becomes increasingly more complex --- until obsolete equipment is removed and replaced (e.g. analog to digital), and strategy process improvement initiatives reach steady state.



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Program Accomplishments FY10 – FY11

Four innovations used for the PSC/Telecom asset strategy

1. **Quantification of regional (societal) costs as well as BPA-incurred costs**
   - Estimates the value of transmission reliability
   - The cost to the region when equipment fails and a **customer** outage occurs

2. **Comprehensive modeling of cost (and avoided cost) uncertainties**
   - A leap forward in quantifying risks
   - Based on historical actuals and extensive coordination with SMEs

3. **New model will enable work to be prioritized to reduce reliability risk and exposure and reduce economic cost**
   - While also taking into account capital funding, outage availability, resource availability, and other constraints

4. **Structured approach to implementation planning**
   - Assumptions, data, and model vetted
   - Replacements and maintenance prioritized in greater detail
   - Redesigned and bolstered processes, including test and evaluation program, technical training, and asset documentation practices
   - Resources allocated

Overall goal: minimize long-term economic cost to BPA and the Region

Economic Modeling In a Nutshell

Simulates over a 30 year period . . .

Captures range of uncertainties

Equipment failures

- Failure curves for old and new equipment
- Based on BPA historical trends, SME judgment, available manufacturer and industry trends

Cost of equipment failures

- Repair/unplanned replacement costs (BPA cost)
- Collateral damage (BPA cost)
- Mandated remedial work (BPA cost)
- Lost customer value – if outage occurs (societal cost)

Equipment replacements and maintenance

- Type of equipment replaced or maintained
- Timing of replacements or maintenance
- Nature of replacement equipment (technology type)
- Number of labor hours needed for the work

Cost of replacements and maintenance

- Equipment costs per unit
- Labor costs per unit
- Spare inventory costs
- Training and documentation costs

Captures range of uncertainties

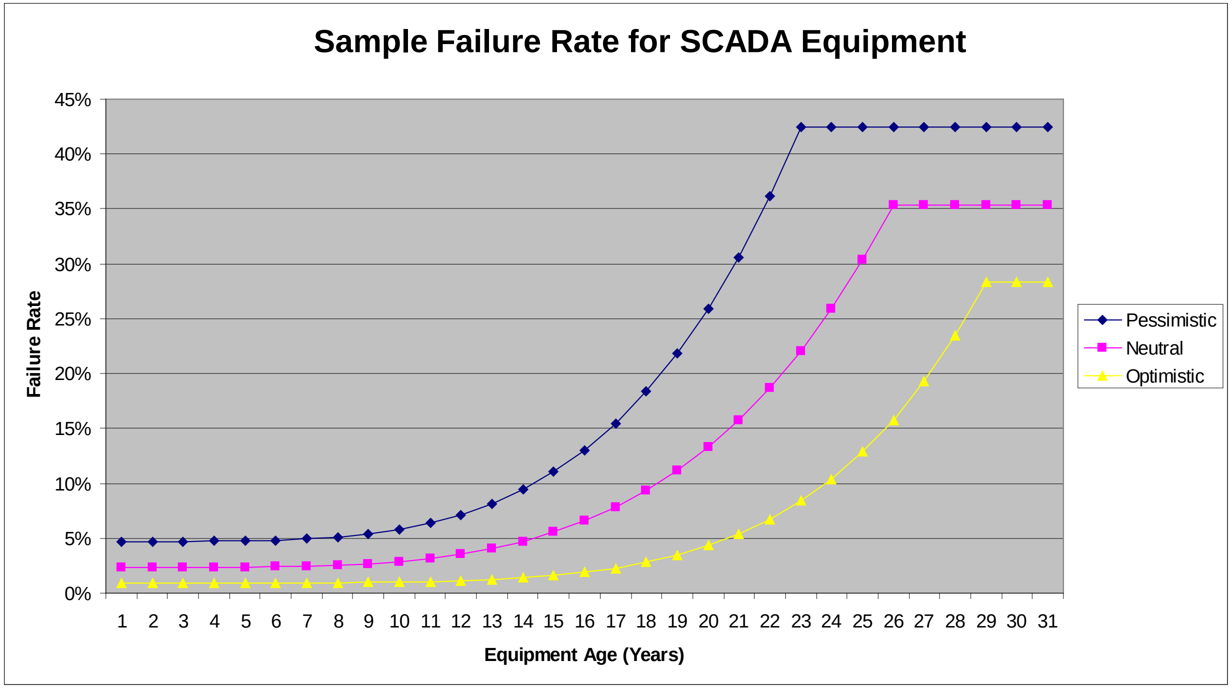
The modeling evaluates a long-term plan of upgrades, replacements and maintenance – by equipment type, by year
Produces expected value costs for BPA and the region – with 80% uncertainty ranges
NPV and capital and expense totals by year
Cost probability curves and key drivers of cost uncertainty
Labor (FTE) requirements by craft/skill group by year
Equipment failure rates by year
Informs outage planning

The Modeling Tool

- An Excel-based planning tool that provides feedback (via economic costs and other indicators) to the planner based on choice, level and timing of replacements
- The model is not an optimization model
- 24 PSC equipment types are modeled - each with different failure, cost, labor and other attributes
- Over 900 inputs
- 80% uncertainty ranges on all model inputs
- Model can be used to determine value of efficiency and productivity improvements
  - Training program improvements
  - Documentation backlog reduction
  - Testing improvements
- Model may be run with capital, human resource, and planned outage constraints applied

Deciding optimal time to repair or replace depends on equipment age, expected life, condition, technological change

- Failure-probability curves were prepared for each of 24 equipment types
- Curves compare age with probable end of life
- The method uses failure-probability (survival) curves that were derived from actual BPA PSC equipment failures coupled with SME judgment



Expected service lives (years)

Pessimistic	12.5
Neutral	16.6
Optimistic	20.2

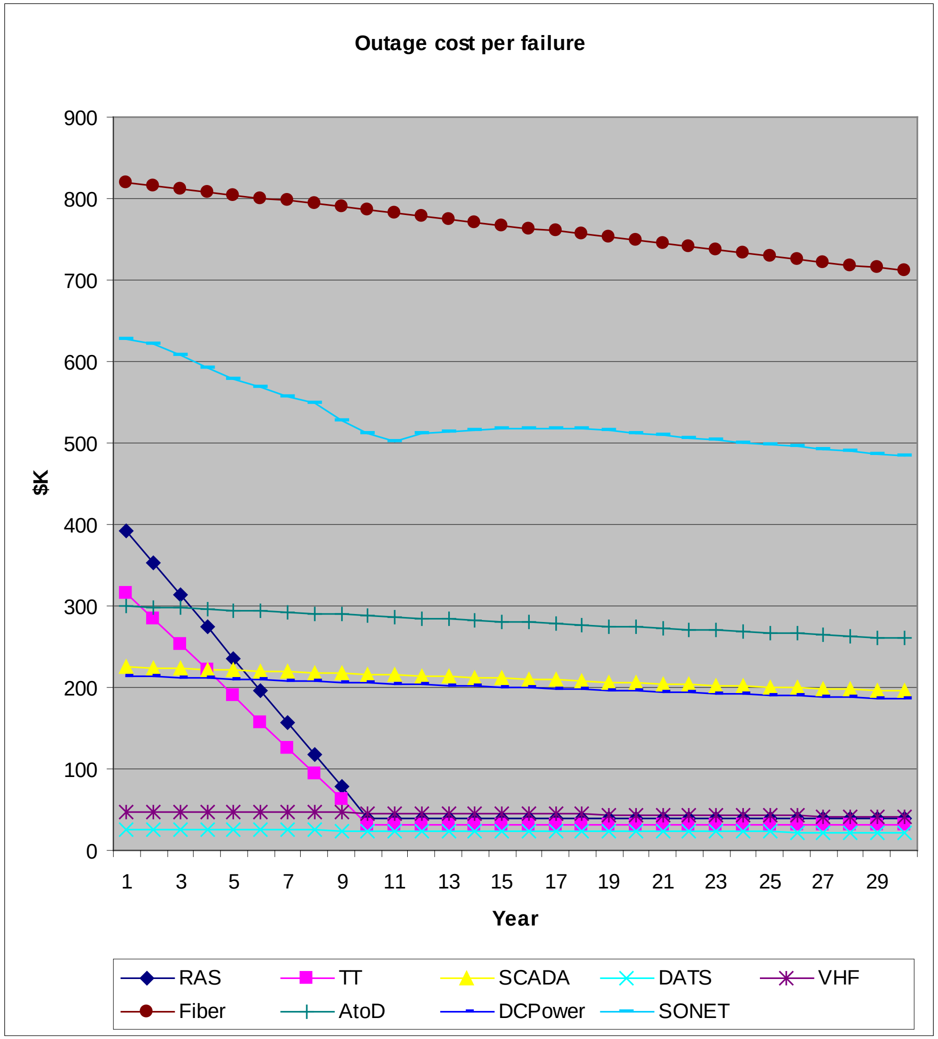
Deciding optimal time to repair or replace ***also*** depends on outage risk and exposure

- Generally, when PSC equipment fails, there is no impact to transmission system operations and reliability because of redundancy and backup measures
- Variables that influence an outage are time of failure (on-peak, off-peak, medium), duration to fix the failed equipment, and the overall status of the system (other outages, equipment failures, etc.)
- Few of the 24 types of PSC equipment could cause a **non-cascading customer outage**
  - Low probability event, with impact limited to less than 100 MW in total customer outage
  - Economic losses could take the form of non-firm revenue loss, customer value loss, equipment damage
- And still fewer types of PSC equipment could cause a **cascading customer outage** – and then only if there are other failures
  - Very, very low probability event – 1 in 100,000 chance
  - *However,* impact could be very high -- up to 30,000 MW outage for day or so and up to $2 to $3 billion in customer value losses
  - For example, overall probability of 30k MW outage given a RAS failure is (Time of Failure X Probability of Transmission Outage X Cascading Outage (Y/N) X Size of Cascading Outage) = 0.5% X 2%X% 6.6% X 1% = 0.0007%

Expected Value of change in the total outage-related cost per equipment failure

- Failures for major PSC equipment types were evaluated and the expected value cost per equipment failure charted to show the change with different program choices

- This approach is valuable for prioritizing replacement program choices to maximize the value of investments over the long term



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Program Accomplishments FY10 – FY11

Rolling Technology Strategy

Aggressively reduce risks of asset failure, interoperability, and technological obsolescence

- **Surmount large backlogs that have resulted from years of under-investment**
  - Accomplish conversion from analog equipment to digital within 7-9 years
    - Replace critical analog Transfer Trip and RAS equipment within five years (accelerate from the current pace of 17-19 years)
  - Implement the projects now in flight (see slide **37**)

- **Design and conduct a comprehensive, integrated testing program**
  - "Test twice, install once"
  - Enhance existing selection and testing programs by adding a field testing phase to the current pre-qualification testing
  - Install enough terminals of a new technology to test for technology interoperability, system limits for timing, geographic distribution, circuit type limitations
  - Coordinate the testing of system components so that roll-outs are efficient and pose minimal risk to system stability
  - Ensure that reliability risk is reduced , time-consuming and expensive re-do's are minimized, and scarce FTE are deployed efficiently

- **Develop and implement a long-term strategy for moving off SONET**
  - Technological obsolescence predicted in 10 years
  - Meanwhile investment in SONET is needed to ensure capacity adequacy, reliability
  - Begin with field operation testing of OMET, then determine deployment

Rolling Technology Strategy

Ensure PSC and telecom equipment is upgraded/replaced to enable the agency to deliver on its strategic initiatives

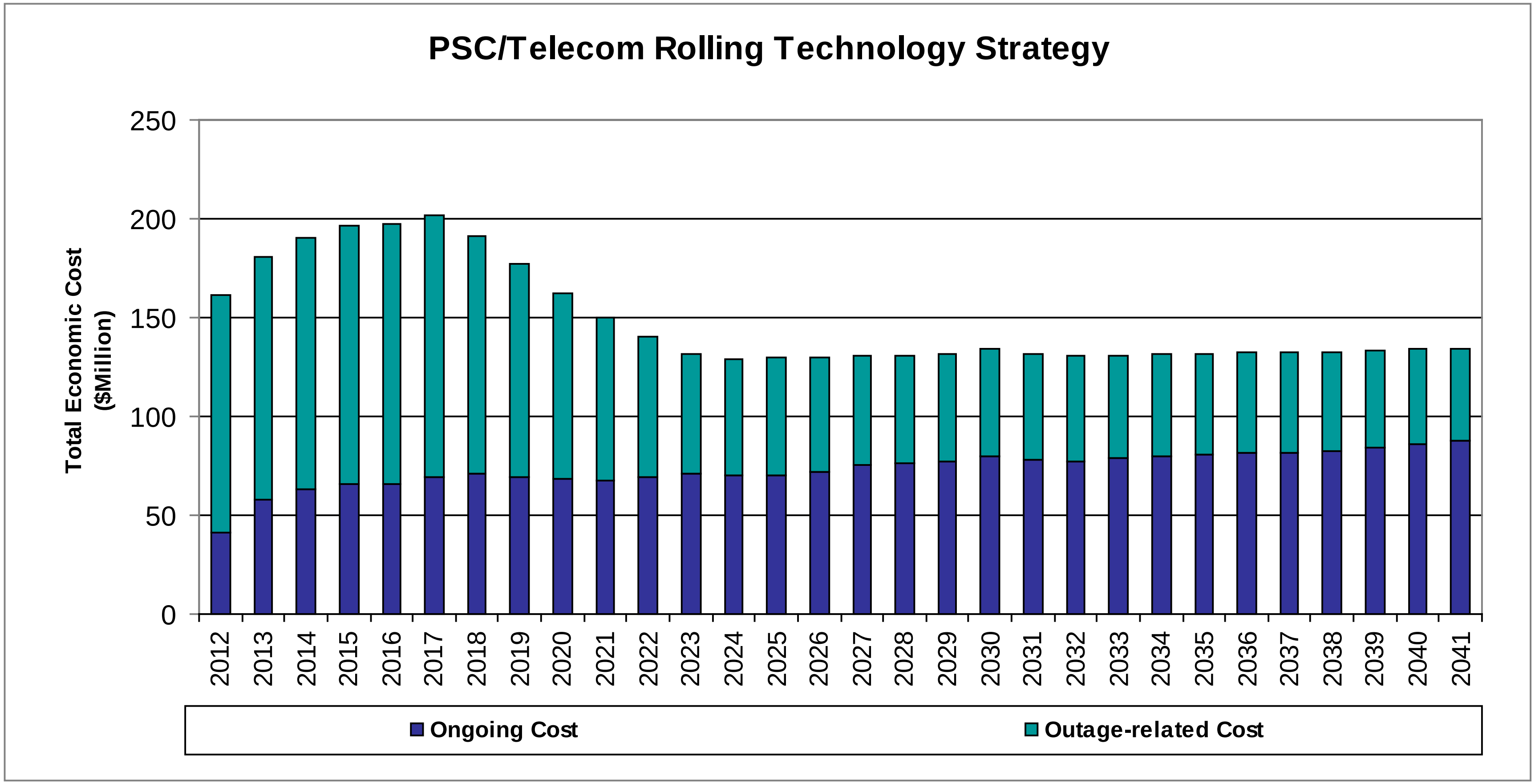
- Such as:
  - Potential formation of an energy imbalance market
  - Potentially greater use of dynamic transfer capacity
  - Potentially greater use of demand response resources
  - Potential move to 15-minute scheduling
  - Technological innovations that enable grid operators to “see” the grid more accurately, intermittent generation to be forecast more accurately, and grid operations to be controlled more precisely

Update the strategy analytics on recurring basis

- Update asset health risk assessments
- Update prioritization of work activities – directed at maximizing total economic value

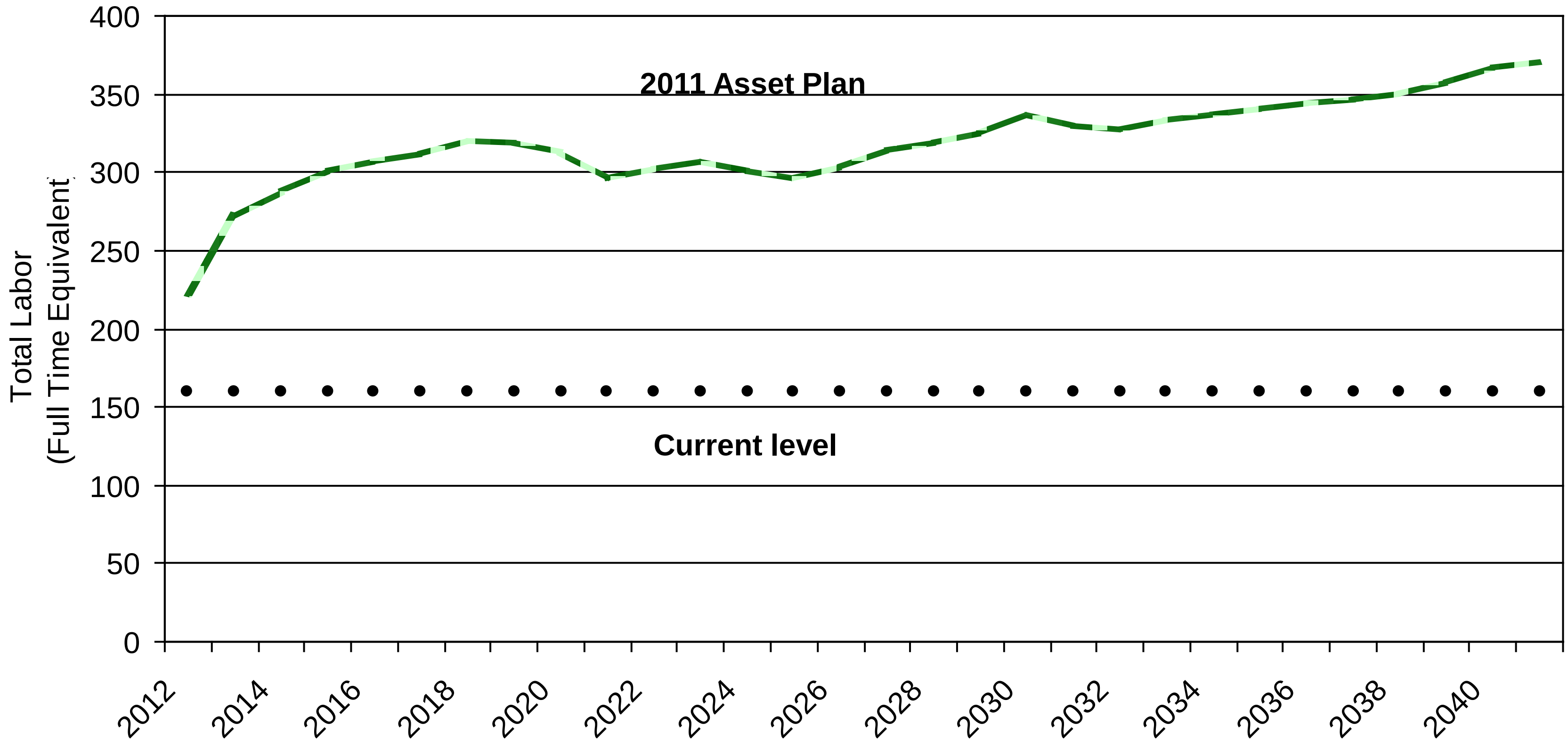
Continue to benchmark with other west coast utilities to learn how they manage PSC assets

The asset plan addresses equipment with higher outage risks and maintenance costs early, which leads to reduced long-term costs



Total Economic Cost is the sum of ongoing costs and outage-related costs (customer value loss)
Ongoing Cost, or BPA-incurred costs, is the sum of materials/equipment and labor costs, whether capital or expense

The plan requires an increase in labor to overcome backlog, implement a shorter technology life-cycle, and accommodate growth of the system.



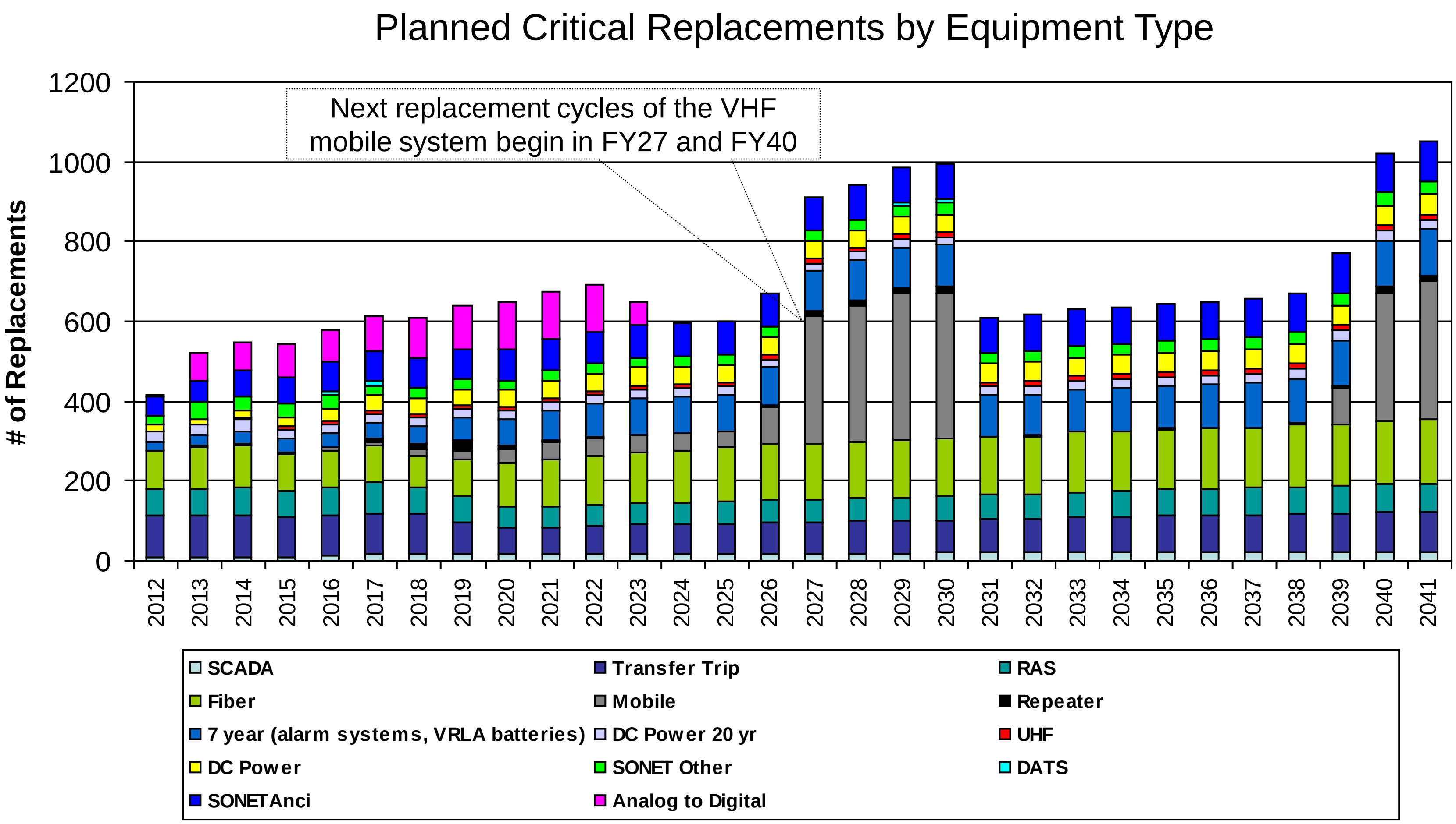
On average, labor costs represent 58 percent of the program's total annual cost

* Excludes the labor for the Mobile Replacement CMO project

Several key working assumptions underlie the development of the model and implementation plan

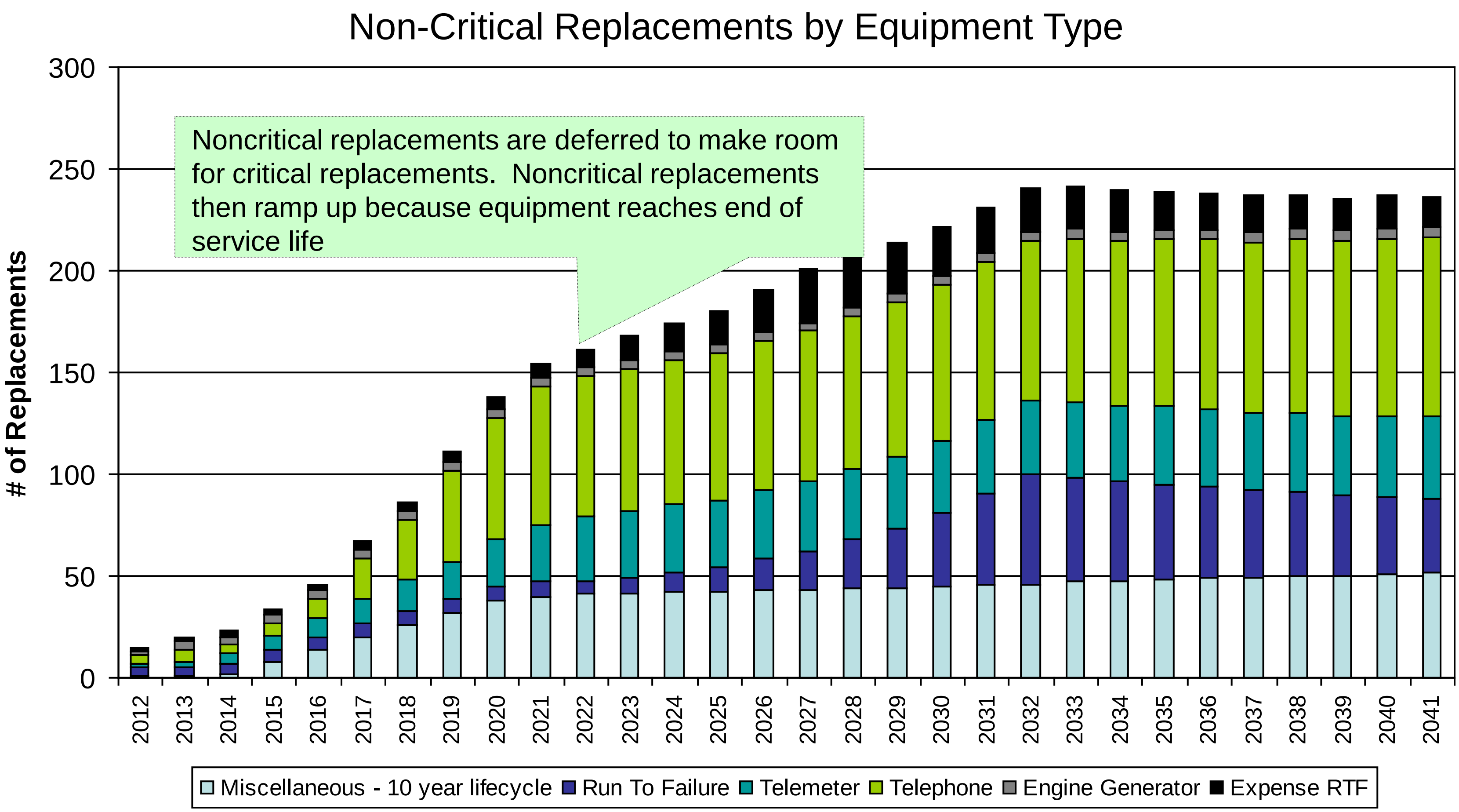
Low impact equipment is repaired until it reaches terminal failure, then replaced (run to fail) rather than having a time-based replacement cycle
Replacement cycles are driven by equipment type, technology and market lifecycles, experience with similar technologies, ability to repair in-house and availability of spares. Adjusted lifecycles by equipment type and extended whenever appropriate
Assume all failures will be repaired to restore service prior to a replacement decision being made, and terminal failure rate is between 2% and 10%
Equipment groupings are based on similarities in system impact, cost, and life cycle
A/D replacements turned to retirements (eliminated duplication between A/D and SONET categories)
Outage risk reassessed for different sizes of outages. High MW/high cost outages much lower risk than low MW/low cost outages

Highest priority is assigned to replacing equipment with the greatest likelihood of failure and the greatest likelihood of transmission outage

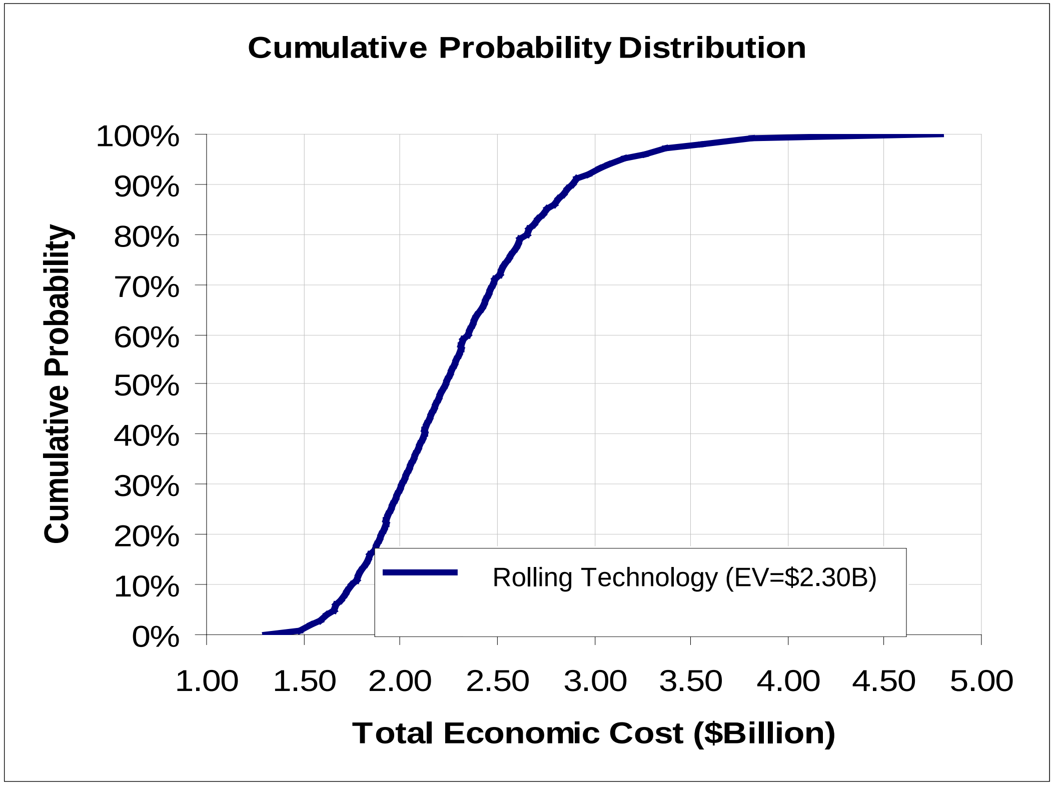


Note: Fiber is measured in miles, all other equipment in numbers of units

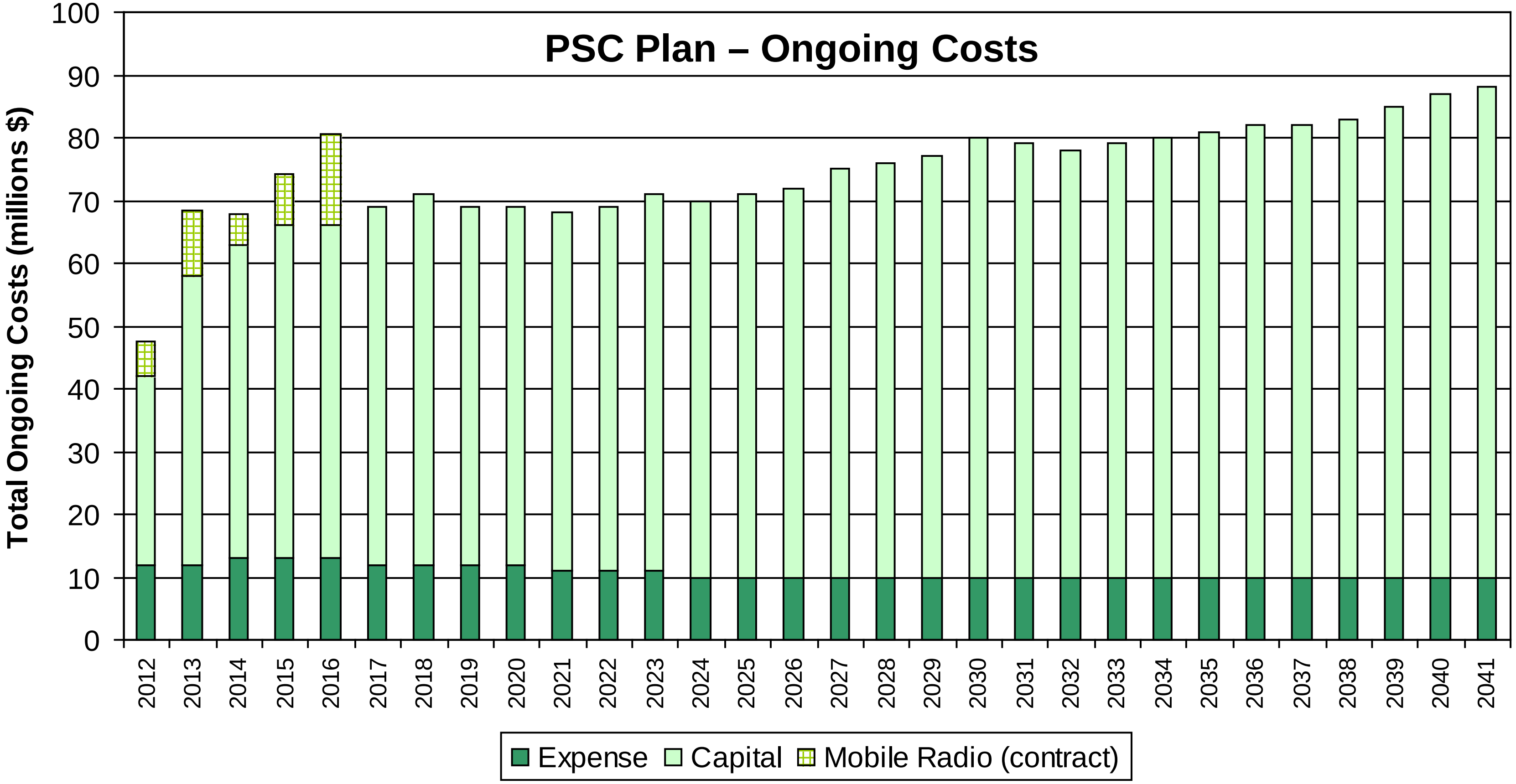
Lower priority is assigned to non-critical equipment



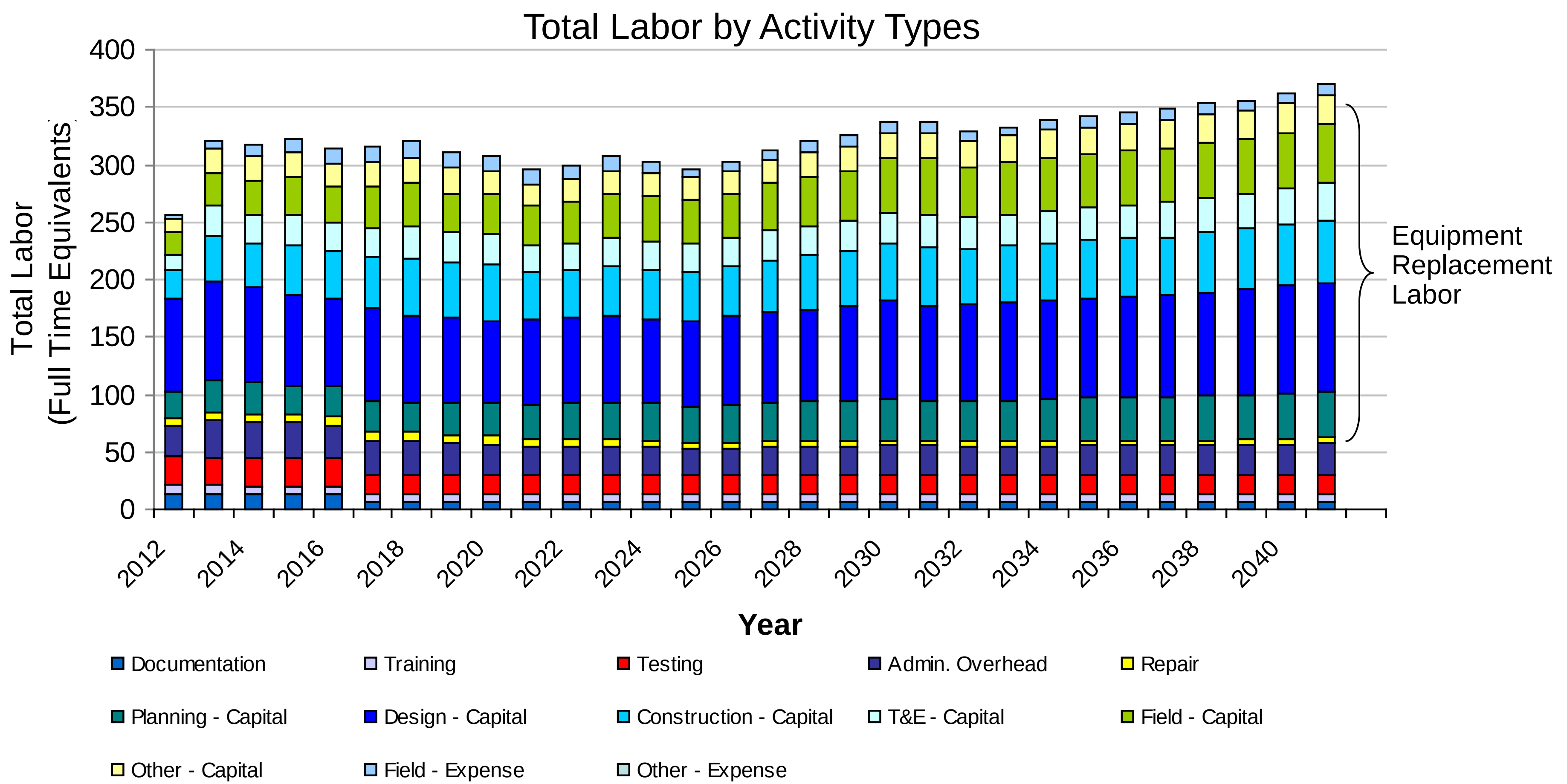
The Rolling Technology implementation plan results in the following probability distribution



At steady state, Ongoing Cost runs at $70 million/year, then grows as the system grows



Significant labor requirements are required to replace PSC equipment. Increases are primarily supplemental labor and contractors.

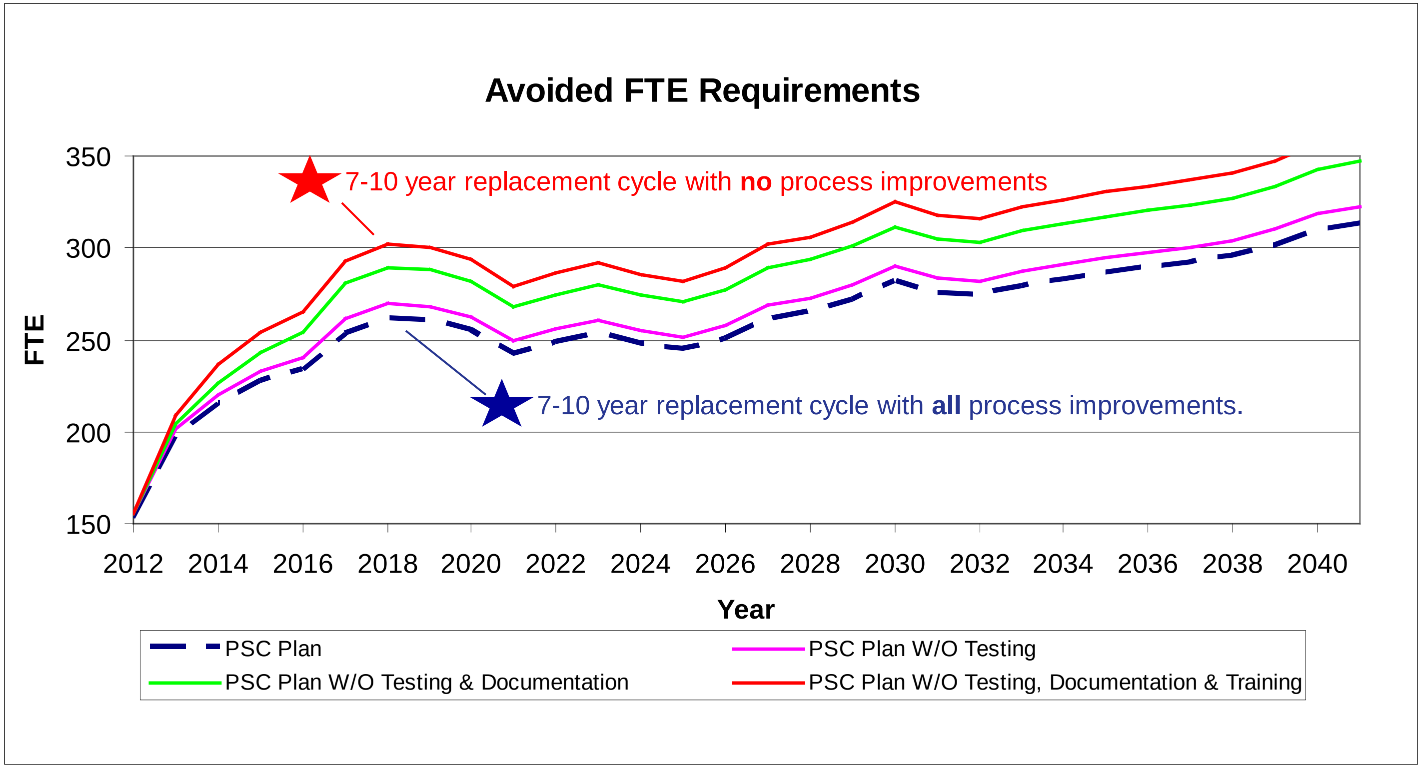


High Value Process Improvements

- Technology Evaluation & Equipment Testing
  - New group of 5 people created to focus on equipment testing
  - Role: Coordinate equipment testing and create annual 5 year testing plan that aligns with equipment replacement plan
  - Council created to provide strategic direction and oversight of technology and testing plan
- Documentation
  - Specialized team created to focus on documentation
  - Short-term will address backlog, long-term maintain in steady state
  - Efficiencies gained through reduction of re-work
- Technical Training
  - PSC Engineer formalized training program
  - Separate rooms for Training and Testing, increase capacity to train
- Plan coordination with Supply Chain, Outage Office, PMO and Resource Managers

Process improvements will yield large FTE savings

(reduced re-work and quicker installations (latest, accurate drawings to work from)



Savings will require management focus and controls over a period of years

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Budget Forecasts

Note: This implementation plan is a replacement program with the optimal funding, staffing resources, and outage availability to best mitigate risks identified in the strategy. These numbers are not aligned with the currently constrained IPR budget. Each sustain program is under review to determine a revised implementation plan that will align with capital budget availability, priorities, and resource constraints. This review will be complete by March 2012.

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FY10 – FY11 Program Accomplishments

The focus of the PSC/Telecom Asset Program during FY10/FY11 was two-fold:

- Complete the strategy development project and implementation planning with SDG.
  - The end result of the strategy effort is a robust, comprehensive implementation plan that utilizes monetized value metrics for equipment condition, equipment reliability risk, and customer value to produce an optimized program designed to maximize investment value and minimize power system reliability risks due to PSC/Telecom equipment failures
- Execution of projects to move the analog to digital migration initiative forward
  - Completed joint fiber ring in the Puget Sound area with Puget Sound Energy
  - Buried approximately 8 miles of problematic fiber optic cable near Augspurger Mtn.
  - Completed Sifton section of #AC SONET
  - #KC Phase 1 Project became operational, allowing circuits to begin moving from the analog microwave along the COI to fiber and digital radio
  - Progress on #NC SONET systems and analog/digital migration

FY10 – FY11 Program Accomplishments

- Completed 20% of EACC circuit cutovers
- Completed replacement of:
  - 27 comm batteries/chargers
  - 7 FLAR remotes
  - 5 SCADA RTUs
  - 11 UHF radios
  - 54 analog comm alarm RTUs
  - 6 antenna systems
  - 3 DATS telephone switches
  - 32 analog Transfer Trip/RAS units
- Received approval for and beginning preliminary design to upgrade over 300 miles of fiber optic cable on the Ross-Schultz fiber project.
- Received approval for and currently implementing “D” system analog radio replacement (#WC Project)
- Received approval for and beginning preliminary design for Mobile Radio Replacement Project