Project Management for Scientists

Work Breakdown Structure & Cost and Schedule Estimates

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Outline

- Work Breakdown Structure (WBS)
- WBS Entries
- Level of Detail
- Work Package Content
- Estimates
- Contingency
- Scheduling

Work Breakdown Structure

- Abbreviated to WBS, also task or activity list
- Decomposition of project into manageable units
  - Understand whole by understanding parts
  - Tree of work required to deliver final product
- Captures scope of project for better scope control
  - Basis of resource assignments
  - Framework for detailed cost estimates, control
  - Guidance for schedule development, control

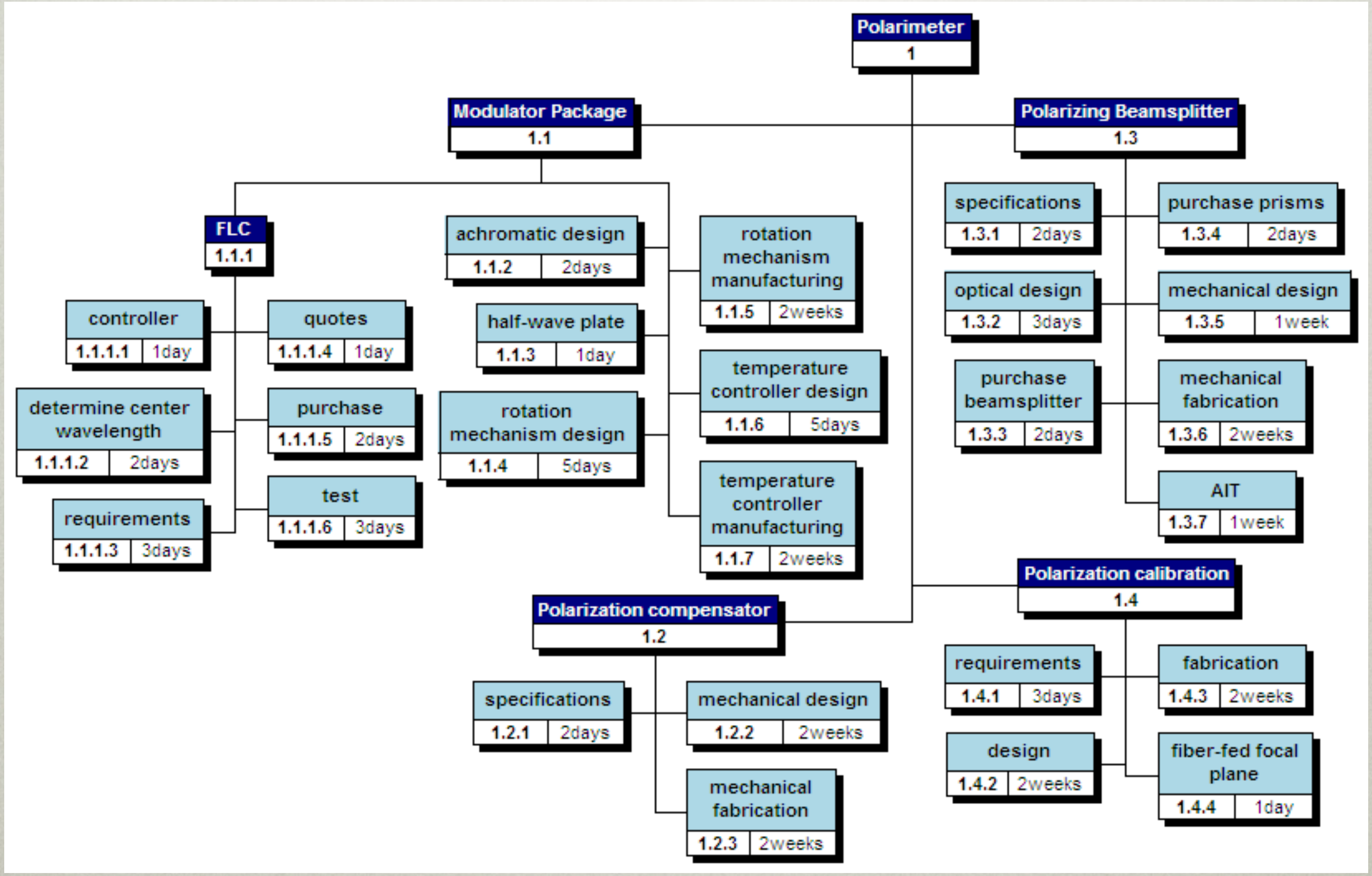
WBS Entries

- **Summary tasks**
  - Include several subordinate tasks
  - By accomplishing all subordinate tasks, summary task is accomplished
  - Summary tasks are not executed
  - Summary of subordinate work packages
- **Work Packages (WP) or terminal tasks**
  - Have no subordinate tasks
  - Are exectued

Example WBS as Task List

ID	WBS	Task Name	Duration
1	**1**	**Polarimeter**	**87 days**
2	**1.1**	**Modulator Package**	**82 days**
3	**1.1.1**	**FLC**	**28 days**
4	1.1.1.1	controller	1 day
5	1.1.1.2	determine center wavelen	2 days
6	1.1.1.3	requirements	3 days
7	1.1.1.4	quotes	1 day
8	1.1.1.5	purchase	2 days
9	1.1.1.6	test	3 days
10	1.1.2	achromatic design	2 days
11	1.1.3	half-wave plate	1 day
12	1.1.4	rotation mechanism design	5 days
13	1.1.5	rotation mechanism manufactu	2 wks
14	1.1.6	temperature controller design	5 days
15	1.1.7	temperature controller manufa	2 wks
16	**1.2**	**Polarization compensator**	**79 days**
17	1.2.1	specifications	2 days
18	1.2.2	mechanical design	2 wks
19	1.2.3	mechanical fabrication	2 wks
20	**1.3**	**Polarizing Beamsplitter**	**76 days**
21	1.3.1	specifications	2 days
22	1.3.2	optical design	3 days
23	1.3.3	purchase beamsplitter	2 days
24	1.3.4	purchase prisms	2 days
25	1.3.5	mechanical design	1 wk
26	1.3.6	mechanical fabrication	2 wks
27	1.3.7	AIT	1 wk
28	**1.4**	**Polarization calibration**	**60 days**
29	1.4.1	requirements	3 days
30	1.4.2	design	2 wks
31	1.4.3	fabrication	2 wks
32	1.4.4	fiber-fed focal plane	1 day

Example WBS Graphics



Creating a Good WBS

- Top-down approach: divide and conquer
- Top level: major deliverables, products, or high-level tasks from Statement of Work (SOW)
- Focus on tasks that have clear deliverables
- Task names have nouns and verbs (design this, produce that, …)
- Break down each task into more detailed tasks

Successful WBS Criteria

- Top-down decomposition
  - Each work package is subset of its summary task
  - Summary tasks provide meaningful project information
- Work packages must add up to summary task
  - No missing tasks
  - Subordinate tasks must produce summary task
- Each task is an activity producing a product
  - No open-ended tasks
  - No nouns without verbs

WBS Level of Detail

- How large should the smallest WBS tasks (work packages) be? Must be manageable.
  - ≥ 1 day
  - ≤ 2 weeks
  - ≤ reporting period
- Smallest WBS task?
  - Can be realistically and confidently estimated
  - Makes no sense to break down any further
  - Produces measurable deliverable
  - Forms work package that can be contracted

Work Package Information

- Unique, hierarchical number (1, 1.1, 1.1.1, …)
- Descriptive name
- Required Input
- Dependence on other WBS entries
- Constraints
- Deliverable(s)
- Cost and time estimates
- Resources needed/assigned
- Due date

Partial WP Example

Work package number	04000	**Start date / End date**	1 / 36
Work Package Title	**Optical Design**		
Activity type	RTD		

Participant nr.	4	2					
Participant short name[1]	THEMIS	KIS					
Person-months per participant [2]	4 (3)	0					
Personnel costs (kEUR)	20	0					
Travel costs (kEUR)	2	2					
Equipment (kEUR)	0	0					
Subcontracts (kEUR)	0	0					
Other costs (kEUR)	0	0					
Total Direct Costs: *24,0 kEUR*	22	2					

Objectives:

Coordinate and control the main optical design production process and optical design subpackages in compliance with general project methodology, providing feedback to Project system engineering and management.

Estimates

- Forecasts of cost, schedule to produce deliverables
- Needed to
  - determine length and cost of project
  - develop baseline plan
  - schedule work ahead of time
  - develop cash flow requirements
  - track progress of project

Types of Estimates

Accurate estimates require accurate specifications

- *Ballpark estimate* (gut feeling of an expert)
  - Very fast, easily wrong by factor of 2
  - Only use to decide whether more accurate estimate should be obtained
- *Rough Order of Magnitude* (ROM)
  - Extrapolation from previous projects
  - Often good enough to start project

Top-Down Estimates

- Fastest, least precise method
- Divide project into major components
- Estimate each component based on previous experience with similar projects
- Adjust for differences between new project and the ones estimate is based on
- Accuracy depends on past experience with similar projects, availability of historical data

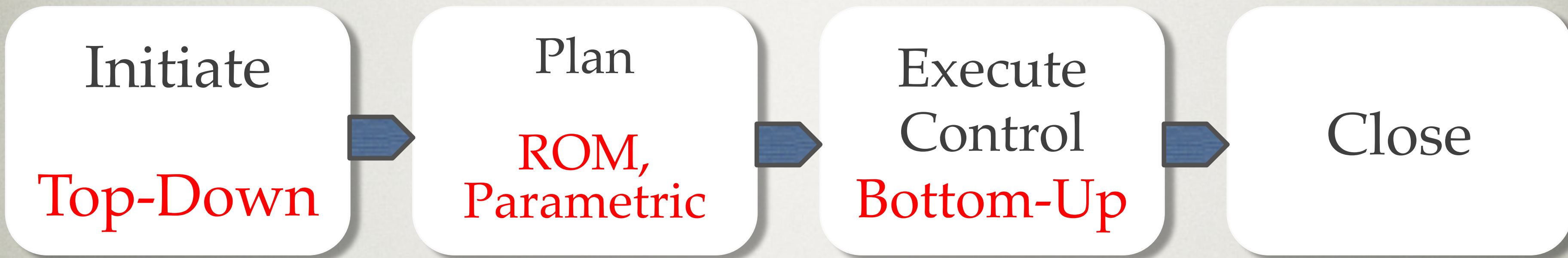
Parametric Estimating

- Uses equation to predict time and cost of future work based on past, completed projects
- Fast if good models and historic data from many projects are available
- Good when estimating something that has been done many times before
- Example: €500 per m^3 for residential house in The Netherlands

Bottom-Up Estimating

- Estimate each work package individually
- Sum up all estimates for total project estimate
- Requires comprehensive and detailed WBS
- Not useful before detailed project planning
- Takes most time, but often most accurate

Phased Estimating



- Estimates become more accurate as project progresses from definition through planning to execution
- Phased estimating uses different estimating techniques for different phases
- Works well in scientific projects

Contingency

- Estimates never 100% certain
- Must cover risk of underestimating cost and unforeseen problems
- For scientific project, at least 20% cost contingency for very well-defined plan
- Otherwise, >100% during definition, >50% during design, >20% for construction
- May have to be hidden as many funding agencies do not allow inclusion of contingency

Milestones

- Mark significant events in a project's life
  - Start, finish of project
  - Input from one party/phase to another
  - Significant events not represented by summary task or work package
  - Major progress points
- Milestones take no time, do not influence schedule

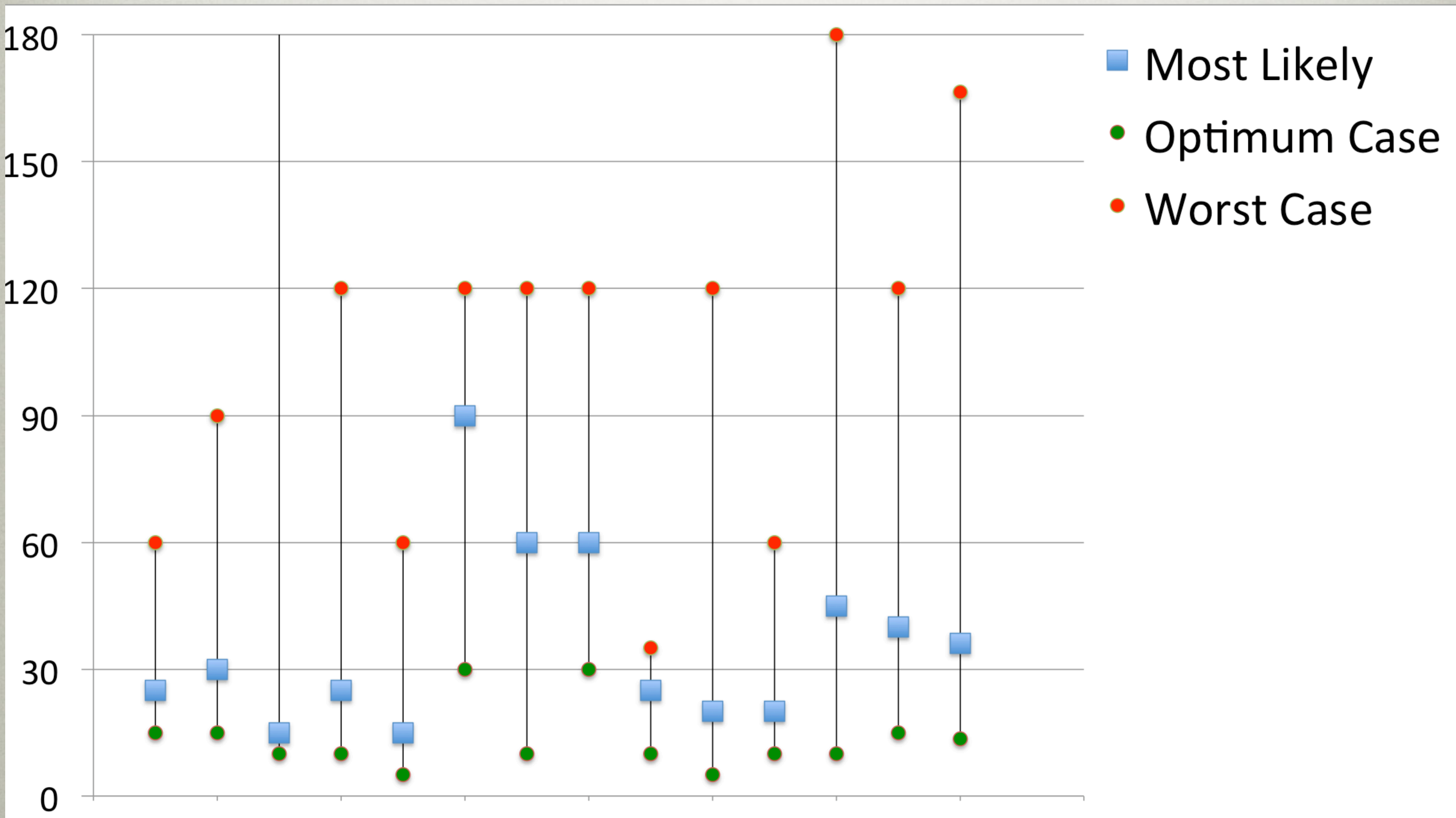
Milestones Example

milestone	updated (Sep. 2008)	proposal (May 2007)	passed?
PhD student starts	March 2008	March 2008	yes
Design Review	February 2009	November 2008	
AIT finished	November 2009	July 2009	
Instrument shipped to the USA	January 2010	November 2009	
First light at SOLIS	March 2010	February 2010	
Start of regular data collection at SOLIS	July 2010	June 2010	
Thesis defense PhD student	April 2012	April 2012	
Minimum instrument lifetime achieved	Jun 2020	May 2020	

Realistic Schedules

- are based on detailed knowledge of effort
- have task sequence in correct order
- account for external constraints beyond control of project team
- can be accomplished on time given access to skilled people and sufficient equipment

Optimistic Estimates



SCHEDULING

1. Based on Work Breakdown Structure
2. Specify person/vendor who will accomplish each work package/task and ask how much time it takes
3. Establish task dependencies between and among tasks
4. Determine completion dates for each task
5. Add this information and assumptions to plan
6. Create overall schedule

Task Dependencies

For each work package ask

- When could it begin?
- When must it begin?
- When could it finish?
- When must it finish?
- Where does it lead to?
- What would be delayed if it slipped?

Determine Task Dependencies

- Task dependencies only exist between work packages (summary tasks consist of work packages)
- Task dependencies only reflect sequence constraints (A must be done before B)
- Schedules are typically made by assuming that task must be completed before successor task can start

Task Dependency Example

ID		Task Name	WBS	Duration	Predecessors
1		**Polarimeter**	**1**	**87 days**	
2		**Modulator Package**	**1.1**	**82 days**	
3		**FLC**	**1.1.1**	**28 days**	
4		controller	1.1.1.1	1 day	
5		determine center wavelen	1.1.1.2	2 days	
6		requirements	1.1.1.3	3 days	4,5,10
7		quotes	1.1.1.4	1 day	6
8		purchase	1.1.1.5	2 days	7
9		test	1.1.1.6	3 days	8
10		achromatic design	1.1.2	2 days	
11		half-wave plate	1.1.3	1 day	
12		rotation mechanism design	1.1.4	5 days	
13		rotation mechanism manufactu	1.1.5	2 wks	12
14		temperature controller design	1.1.6	5 days	7
15		temperature controller manufa	1.1.7	2 wks	14
16		**Polarization compensator**	**1.2**	**79 days**	
17		specifications	1.2.1	2 days	
18		mechanical design	1.2.2	2 wks	
19		mechanical fabrication	1.2.3	2 wks	18
20		**Polarizing Beamsplitter**	**1.3**	**76 days**	
21		specifications	1.3.1	2 days	
22		optical design	1.3.2	3 days	21
23		purchase beamsplitter	1.3.3	2 days	22
24		purchase prisms	1.3.4	2 days	22
25		mechanical design	1.3.5	1 wk	
26		mechanical fabrication	1.3.6	2 wks	25
27		AIT	1.3.7	1 wk	23,24,26
28		**Polarization calibration**	**1.4**	**60 days**	
29		requirements	1.4.1	3 days	
30		design	1.4.2	2 wks	
31		fabrication	1.4.3	2 wks	30
32		fiber-fed focal plane	1.4.4	1 day	

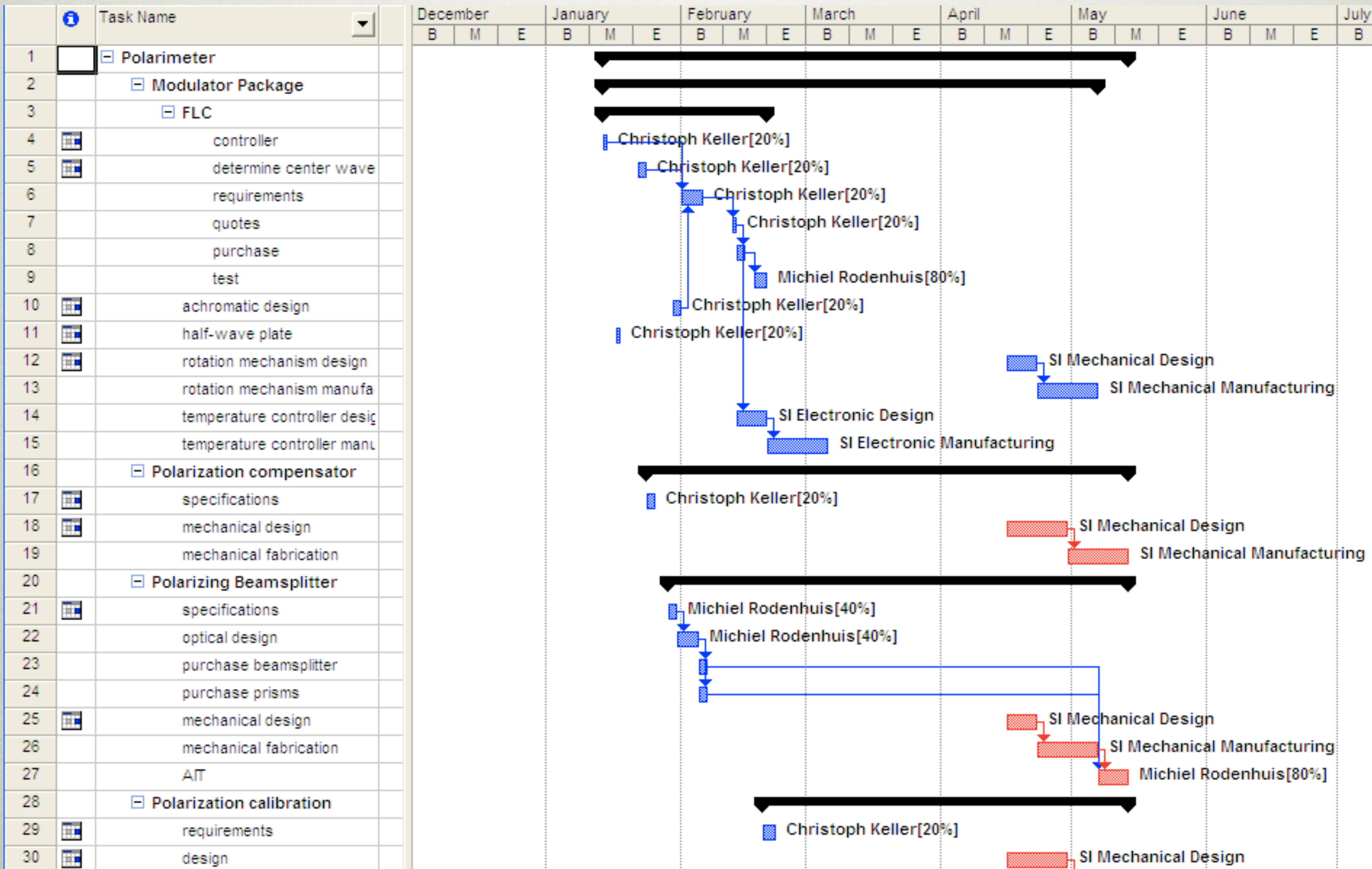
Labor Estimate vs Duration

- People not available 100% of time
- People not 100% efficient
- Decisions can take significant time to get to
- Ordering is quick, delivery can take long time
- Labor estimate = time it takes somebody working 100% on task to finish it
- Duration estimate = time that passes on the clock until task is finished

Example Resource Assignment

		Task Name	WBS	Duration	Resource Names	Predecessors
1		⊟ **Polarimeter**	**1**	**87 days**	[redacted]	
2		⊟ **Modulator Package**	**1.1**	**82 days**		
3		⊟ **FLC**	**1.1.1**	**28 days**		
4		controller	1.1.1.1	1 day	Christoph Keller[20%]	
5		determine center wave	1.1.1.2	2 days	Christoph Keller[20%]	
6		requirements	1.1.1.3	3 days	Christoph Keller[20%]	4,5,10
7		quotes	1.1.1.4	1 day	Christoph Keller[20%]	6
8		purchase	1.1.1.5	2 days		7
9		test	1.1.1.6	3 days	Michiel Rodenhuis[80%]	8
10		achromatic design	1.1.2	2 days	Christoph Keller[20%]	
11		half-wave plate	1.1.3	1 day	Christoph Keller[20%]	
12		rotation mechanism design	1.1.4	5 days	SI Mechanical Design	
13		rotation mechanism manufa	1.1.5	2 wks	SI Mechanical Manufacturing	12
14		temperature controller desi	1.1.6	5 days	SI Electronic Design	7
15		temperature controller manu	1.1.7	2 wks	SI Electronic Manufacturing	14
16		⊟ **Polarization compensator**	**1.2**	**79 days**		
17		specifications	1.2.1	2 days	Christoph Keller[20%]	
18		mechanical design	1.2.2	2 wks	SI Mechanical Design	
19		mechanical fabrication	1.2.3	2 wks	SI Mechanical Manufacturing	18
20		⊟ **Polarizing Beamsplitter**	**1.3**	**76 days**		
21		specifications	1.3.1	2 days	Michiel Rodenhuis[40%]	
22		optical design	1.3.2	3 days	Michiel Rodenhuis[40%]	21
23		purchase beamsplitter	1.3.3	2 days		22
24		purchase prisms	1.3.4	2 days		22

Gantt Chart


Task Name
December
January
February
March
April
May
June
July
B M E
1 Polarimeter
2 Modulator Package
3 FLC
4 controller
5 determine center wave
6 requirements
7 quotes
8 purchase
9 test
10 achromatic design
11 half-wave plate
12 rotation mechanism design
13 rotation mechanism manufa
14 temperature controller desig
15 temperature controller manu
16 Polarization compensator
17 specifications
18 mechanical design
19 mechanical fabrication
20 Polarizing Beamsplitter
21 specifications
22 optical design
23 purchase beamsplitter
24 purchase prisms
25 mechanical design
26 mechanical fabrication
27 AIT
28 Polarization calibration
29 requirements
30 design
Christoph Keller[20%]
Christoph Keller[20%]
Christoph Keller[20%]
Christoph Keller[20%]
Michiel Rodenhuis[80%]
Christoph Keller[20%]
Christoph Keller[20%]
SI Mechanical Design
SI Mechanical Manufacturing
SI Electronic Design
SI Electronic Manufacturing
Christoph Keller[20%]
SI Mechanical Design
SI Mechanical Manufacturing
Michiel Rodenhuis[40%]
Michiel Rodenhuis[40%]
SI Mechanical Design
SI Mechanical Manufacturing
Michiel Rodenhuis[80%]
Christoph Keller[20%]
SI Mechanical Design

Cash Flow Plan

- Determine when money is going to be spent
- Requires both cost estimates and schedule
- Can be easily calculated
- Often an issue in scientific projects because funding agencies will only provide equal payments per period
- Project sponsor may have to play the bank

Cash Flow Plan Example

	Year 1	Year 2	Year 3	Year 4	Year 5
Personnel					
Postdoc (5 years ,vacant)	55000	55000	55000	55000	55000
PhD student A (4 years, vacant)	38000	39000	39500	40000	0
PhD student B (4 years, vacant)	0	38000	39500	40000	39000
Equipment etc.					
Equipment	112000	86000	83000	16000	5000
Consumables	5000	5000	5000	5000	5000
Workshop/Conference	0	0	35000	0	0
Travel	10000	10000	10000	10000	10000
Cash Needed	220000	233000	267000	166000	114000
Cash Available	189200	189200	189200	189200	189200
Cash Needed - Available	**30800**	**43800**	**77800**	**-23200**	**-75200**