INTEGRATED PROJECT MANAGEMENT:
A Case Study in Integrating Cost, Schedule, Technical, & Risk Areas

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INTEGRATED PROJECT MANAGEMENT

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  - ESTIMATE DEVELOPMENT
- CONVERGING PATHS
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- IT ALL COMES TOGETHER
- LESSONS LEARNED
OBJECTIVES

- To demonstrate the practical application of good integrated project management principles to a real project

- To endorse those project management principles that support a successfully managed effort

- To share the pain and rewards of discovery with others so that they may avoid the pain and embrace the rewards
CASE STUDY BACKGROUND

- The International Space Station (ISS) fluid filtration system uses disposable cartridges.
- These cartridges were procured from a contractor who developed the fluid filtration system.
- The contractor “lost” the cartridge technology and could no longer provide off-the-shelf replacements.
- The contractor offered to “re-design” and fabricate the replacement cartridges for a cost.
- The ISS Program Office (ISSPO) decided to pursue developing the cartridges “in-house.”
GETTING STARTED

A need was identified

- Replacement cartridges for ISS fluid filtration system

Expectations were conveyed – at a high level

- Time Frame = X years
- Budget = $X M

The project team was formed

- Work scope was discussed – the conceptual plan was developed
- Preliminary roles were defined - an informal OBS was developed

Detailed planning began

- A WBS template was obtained with a product-orientated structure
- The template was modified by the project team to suit the project
EXAMPLE OF WBS TEMPLATE

Project Name
1.0

Management
1.1
  Business
1.1.1
  Program
1.1.2
  System Engineering
1.2
  Requirements
1.2.1
  Integration
1.2.2
  Configuration
1.2.3
  Hardware
1.2.4
  Software
1.2.5

Mission Assurance
1.3
  Safety
1.3.1
  Reliability
1.3.2
  Hardware
1.3.3
  Software
1.3.4

Element
1.4

Ground Systems
1.5
  Facilities
1.5.1
  Transportation
1.5.2
  GSE
1.5.3
  MGSE
1.5.3.1
  EGSE
1.5.3.2

Test
1.6
  Ground
1.6.1
  Flight
1.6.2
  Facilities
1.6.3
  Software
1.6.4
  Hardware
1.6.5
  GSE
1.6.6

Operations
1.7
  Mission
1.7.1
  Launch
1.7.2
  GSE
1.7.3
  MGSE
1.7.3.1
  EGSE
1.7.3.2

Vehicle
1.4

Upper Stage
1.4.1
  Integration
1.4.1.1
  Airframe
1.4.1.2
  Propulsion
1.4.1.3
  Avionics & Flight Control
1.4.1.4
  Mech. & Fluid System
1.4.1.5

XX Stage
1.4.2
  Integration
1.4.2.1
  Airframe
1.4.2.2
  Propulsion
1.4.2.3
  Avionics & Flight Control
1.4.2.4
  Mech. & Fluid System
1.4.2.5

Booster
1.4.3
  Integration
1.4.3.1
  Airframe
1.4.3.2
  Propulsion
1.4.3.3
  Avionics & Flight Control
1.4.3.4
  Mech. & Fluid System
1.4.3.5

Integration
1.4.4
  MGSE
1.6.6.1
  EGSE
1.6.6.2

6
EXAMPLE OF MODIFIED WBS (2 OF 2)
DEVELOPING THE PLAN

☐ The WBS provided a document outline to begin

☐ A WBS dictionary from another project was used as a reference to draft a "straw man" document

☐ The project team developed definitions together

☐ This was an iterative process that resulted in some minor WBS revisions (important point)

☐ Activities required to complete WBS elements were discussed in some detail
EXAMPLE OF A WBS DICTIONARY

1.1. Management - Includes all aspects of program & project management, control, and coordination.

1.1.1. ISS Program Office (ISSPO) - All activities involving personnel from the ISSPO. This includes those authorized to act on behalf of the ISSPO that are not assigned to the project by the MSFC project manager.

1.1.2. Project Management - All activities required to manage the project according to the applicable PNP, NPG, MMJ, and MWI, including, but not limited to: managing the project, development, administration, and maintenance of the Project Plan, Project Risk Plan, and other related documentation not specifically covered elsewhere, and project meetings and reviews (formal and informal).

1.1.3. Project Control - All activities required by applicable PNP, NPG, MMJ, and MWI, including, but not limited to: project planning, scheduling, budgeting, data management, measurement, analysis, and control measures, including all activities related to establishing an Earned Value System (EVS).

1.2. Systems Engineering & Integration

1.2.1. Specifications

1.2.1.1. Interfaces - All activities associated with identifying and documenting interfaces between the Gas Trap Insert and other components and systems it will interact with.

1.2.1.2. Requirements - All activities associated with identifying and documenting system-level requirements for the Gas Trap Insert.

1.2.2. Conceptual Design - All activities related to the identification and definition of the Gas Trap Insert hardware, including all activities associated with the conceptual design and development of the Gas Trap Insert.

1.2.3. Component & Systems Integration - All activities related to the determination of chemical and mechanical compatibility between all of the Gas Trap Insert hardware pieces, as well as the Gas Trap Insert Assembly's compatibility with the environment in which it is to be installed.

1.2.4. Configuration & Data Management

1.2.4.1. Configuration Management - All activities covering the control of configuration identification, control, accounting, and verification of the Design Requirements, Design, and Hardware documentation for the Project.

1.3. Safety & Mission Assurance

1.3.1. Safety - All activities related to ensuring safety of the Gas Trap Insert hardware, and the environment (earth and space) in which it will operate.

1.3.2. Reliability - All activities related to ensuring availability and maintainability of the Gas Trap Insert hardware.

1.3.3. Quality - All activities involving the improvement of product quality.

1.4. Gas Trap Hardware

1.4.1. Hydrophilic Membrane - All activities involved in the design, analysis, manufacture, and testing of the Hydrophilic Membrane material.

1.4.2. Hydrophobic Membrane - All activities involved in the design, analysis, manufacture, and testing of the Hydrophobic Membrane material.

1.4.3. End Caps - All activities concerned with the design and manufacture of the End Caps.

1.4.4. End Plates - All activities concerned with the design, manufacture, and test of the End Plates.

1.4.5. O-Rings - All activities concerned with the design, manufacture, and test of the O-Rings.

1.4.6. Stress - All activities concerned with the design, manufacture, and test of the Stress.

1.4.7. Property - All activities concerned with the design, manufacture, and test of the Property.

1.4.8. Assembly - All activities associated with the assembly and testing of the Gas Trap Insert.

1.5. Ground Systems

1.5.1. Facilities - All activities involving the development of the Gas Trap Insert for use in ground processes, do not remain in the Gas Trap Insert Assembly's facility, including the development and implementation of the Gas Trap Insert Assembly's facility.

PAGE 1 OF 3
DIVERGING PATHS (REALLY?)

- Yes AND No - parts of schedule development *can* done in parallel with parts of estimate development, but other parts of schedule development *must* be done *before* the estimate *can be completed*

- Schedule Development
  - The WBS outline was used to create an initial schedule structure – actually, just a list of activities with no sequence
  - The schedule development effort began by better defining the activities (i.e. adding detail where needed)
  - Once defined, the process of relating the activities to one another sequentially (i.e. establishing network logic) began
  - No date constraints were used except for the Project Start
  - Technical performance measures (TPM’s) were discussed, agreed upon, and documented (*important point*) – there are many varied methods
EXAM PLES OF TPM'S (1 OF 2)

☐ Percent Complete
☐ Subjective – requires someone to estimate physical progress
☐ Least desirable, most used

☐ Objective – utilizes physical counts to determine progress
☐ Most desirable, least used

"I'd say we're about 25% complete"

"We've built 50 of the 100 widgets, therefore we're 50% complete"
EXAMPLES OF TPM’S (2 OF 2)

- **Milestone**
  - 0-100% - credit is only earned upon completion (100%)
    - Typically used when tasks span <= 1 acct. period
  - 50-50% - credit is given at the start (50%) and finish (50%)
    - Typical for tasks spanning 2-3 acct. periods
  - Weighted – partial credit is given at key interims
    - Used when tasks span more than 3 acct. periods

**NOTE ON MILESTONE TPM: REQUIRES THE USE OF A TRACKING PROCESS**
DIVERGING PATHS (REALY?)

☐ Schedule Development (Continued)

☐ The tasks of making duration estimates and doing resource identification, assignments and allocations were done hand-in-hand since the skill level (for people) and availability of resources have a direct impact on the activity duration.

☐ Not one, but three duration estimates were collected for each schedule activity (best case, worst case, most likely – more on this later).

☐ Every work group (engineers, manufacturing, etc.) participated in developing the schedule – this resulted in a highly integrated plan.

☐ This process was iterative – adjustments to the sequencing of activities and allocation of resources were made until all stakeholders were satisfied with the results.

☐ As duration estimates were finalized, the SAME PEOPLE provided inputs for the cost estimates.
# EXAMPLE SCHEDULE BASED ON WBS

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<th>ID</th>
<th>WBS</th>
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</table>
DIVERGING PATHS (REALLY?)

- Estimate Development
  - Initial estimates were compiled by combining work group leads’ estimates (i.e. X heads for Y months) with rates for labor, procurements, and indirect costs – this process was heavily influenced by historical data
  - As schedule development evolved, costs for resources were loaded in the schedule tool and the resulting time-phased cost plan from the schedule tool was compared with initial estimates
  - The cost, schedule, and work groups collaborated to reconcile the gaps between cost and schedule
  - Initial reserves (cost and schedule) were added based on historical data, but later reviewed and revised (see Establishing the Baseline)
# EXAMPLE ESTIMATE WORKSHEET

<table>
<thead>
<tr>
<th>Object Level</th>
<th>FY05</th>
<th>FY06</th>
<th>FY07</th>
<th>TOTAL</th>
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<td>9051 Civil Service</td>
<td>FTE's</td>
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<tr>
<td>9052 Contractor on-site</td>
<td>WYE's</td>
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</table>

**Workforce total**

<table>
<thead>
<tr>
<th>1000 Personnel</th>
<th>Direct Civil Service FTE x rate</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(Salary &amp; Fringe)</td>
</tr>
</tbody>
</table>

| 2100 Travel    |                                  |
| 3000 Procurement | Contracts, grants, hardware, direct services |

**SUB TOTAL Direct Cost**

<table>
<thead>
<tr>
<th>8020 Service Pools</th>
<th>(FTE+WYE)*Service Pool rate</th>
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</thead>
<tbody>
<tr>
<td>8005 Center G&amp;A</td>
<td>(FTE+WYE)*Center G&amp;A rate</td>
</tr>
<tr>
<td>8000 Corp G&amp;A</td>
<td>(FTE+WYE)*Corp. G&amp;A rate</td>
</tr>
</tbody>
</table>

**Total Full Cost Budget Plan**

- Reserve (15% - held by ISSPO/OB)
- Grand Total
CONVERGING PATHS

☐ Risky Business

☐ The schedule data was used to initially populate a Risk Log template (including best case, worst case, and most likely duration estimates for use later)

☐ The project team adopted a list of risk-types that applied to the project (e.g. design engineering difficulty, manufacturing process difficulty, etc.)

☐ For each risk-type, the project team defined a scale that consisted of numbers with a description for each number (e.g. a “0” for design engineering difficulty might mean “we do it all the time” while a “25” might mean “never done before”)

☐ The same type of scale was developed for the consequence of risk materialization as well

☐ The Risk Log items were examined by the project team and risks were rated using the scales developed as described in the preceding steps

☐ These risk ratings were converted via formulas into a Performance Difficulty factor, as well as an overall Risk Factor, for each Risk Log item

☐ The results were plotted on a standard 5 X 5 Risk Matrix and ranked
### EXAMPLE RISK TEMPLATE (1 of 3)

#### MANUFACTURING PROCESS DIFFICULTY (MPD) RATING

| No comparable process, and at least one of C, Y, T, or P is expected to exceed state of art | 25 |
| No comparable process, and all of the requirements for C, Y, T, and P are expected to be within the state of the art | 16 |
| Incompatible processes are a combination of demonstrated processes and processes that have been adapted, combined, and integrated to achieve C, Y, T, or P | 12 |
| Existing processes are a combination of existing processes and new processes that have been adapted, combined, and integrated to achieve C, Y, T, or P | 6 |
| Existing processes and new processes are within the norm for these processes | 6 |
| New processes are required to meet the requirements for C, Y, T, or P | 3 |

#### DESIGN ENGINEERING DIFFICULTY (DED) RATING

| No alternative and/or requires new or breakthrough advance | 25 |
| No alternative and/or major engineering development using existing knowledge | 20 |
| No alternative and/or new component development is required | 15 |
| No alternative and/or new component is required | 12 |
| New component is required | 9 |
| New component is required and standard components are within specs | 6 |
| New component is required and requires qualification of the shelf item | 3 |

#### PRODUCTION EQUIPMENT STATUS (EPS) RATING

| Insufficient facilities and equipment development required | 25 |
| Facility available, and equipment development not required | 18 |
| Facility is available, but equipment is not available | 12 |
| Equipment modification is required to conform to process | 9 |
| Facility equipment available, but refurbishment required | 6 |
| Facility equipment available, limited use of designated production equipment being used to manufacture given product | 3 |

#### MATERIAL RE-SOURCE STATUS (MRS) RATING

| No defined source | 25 |
| Single off-the-shelf source identified with insufficient material production | 20 |
| Single U.S. source identified with insufficient material production | 20 |
| Multiple U.S. source identified with insufficient material production | 18 |
| Single off-the-shelf source identified with sufficient material production | 16 |
| Multiple off-the-shelf source identified with sufficient material production | 15 |
| Single U.S. source identified with sufficient material production | 10 |
| Multiple U.S. sources with sufficient material | 9 |

#### PERSONNEL RESOURCE STATUS (PER) RATING

| Recruit personnel required for production personnel | 25 |
| Insufficient high skilled production personnel | 20 |
| Insufficient moderate-low skilled personnel | 18 |
| Insufficient production personnel required | 10 |
| Insufficient trained production personnel | 5 |
| Insufficient trained production personnel involved in on-going production | 3 |

#### TEST RESOURCE STATUS (TEST) RATING

| No defined test procedures, no equipment and no test resource available | 25 |
| Defined procedures, insufficient equipment/facility, custom equipment design required | 20 |
| Defined procedures, facility available, standard equipment design required | 12 |
| Defined procedures, facility available, standard equipment required but insufficient equipment available | 9 |
| Defined procedures, facility available, equipment required but refurbishment required | 5 |
| Defined procedures, facility available, equipment available | 3 |

#### Consequence of Failure (C-F) Scale

<table>
<thead>
<tr>
<th>Rating</th>
<th>Consequence</th>
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<tbody>
<tr>
<td>1.0</td>
<td>System failure (e.g., catastrophic failure, mission failure)</td>
</tr>
<tr>
<td>0.5</td>
<td>Major/minor failure (e.g., loss of function, minor injury)</td>
</tr>
<tr>
<td>0.1</td>
<td>Minor failure (e.g., temporary loss of function)</td>
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</table>

#### Probability Distribution Curve

<table>
<thead>
<tr>
<th>Probability Distribution Curve</th>
</tr>
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<tbody>
<tr>
<td>1. Uniform</td>
</tr>
<tr>
<td>2. Triangular</td>
</tr>
<tr>
<td>3. Normal</td>
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</tbody>
</table>
## EXAMPLE RISK TEMPLATE (2 of 3)

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<th>Title</th>
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<th>DE</th>
<th>MPD</th>
<th>LOP</th>
<th>MAT</th>
<th>PER</th>
<th>TST</th>
<th>CF</th>
<th>Pr</th>
<th>Prm</th>
<th>Pls</th>
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### Gas Trap Hardware

- **Hydrophilic Membrane**
  - Specification: 0.98
- **Hydrophilic Membrane Design & Analysis**
  - Specification: 0.98
  - Material not available in the time frame required: 0.98
  - Facilities not available in the time frame required: 0.98
- **Hydrophilic Membrane Manufacturing**
  - Design: 0.98
  - Testing: 0.98
- **End Caps**
  - Design: 0.98
  - Testing: 0.98
- **End Plates**
  - Design: 0.98
  - Testing: 0.98
- **D-Rings**
  - Design: 0.98
  - Testing: 0.98
- **Stiffener**
  - Design: 0.98
  - Testing: 0.98
- **Glue**
  - Design: 0.98
  - Testing: 0.98
- **Ground Systems Development**
  - Facilities Development: 0.98
  - Transportation Development: 0.98
  - GSE Development: 0.98
  - GCSE Development: 0.98

### Testing & Evaluation

- **Qualification Testing**
  - Test fails: 0.98
  - Test fails: 0.98
- **Acceptance Testing**
  - Test fails: 0.98
  - Test fails: 0.98
- **Fleet Leader Testing**
  - Test fails: 0.98
- **Compliance Testing**
  - Test fails: 0.98
  - Test fails: 0.98
- **Qualification Testing**
  - Test fails: 0.98

### Sustainability

- **JE JACOBS SVERDRUP**
  - NASA logo

---

20
EXAMPLE RISK TEMPLATE (3 of 3)

<table>
<thead>
<tr>
<th>WBS</th>
<th>Title</th>
<th>CI</th>
<th>PD</th>
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</table>
ESTABLISHING THE BASELINE

☐ The risk data, along with data collected during interviews, was used to characterize schedule tasks

☐ This characterization and the 3 duration estimates collected earlier were used to perform a schedule risk assessment

☐ Since the schedule was resource loaded and resources were costed, a cost risk assessment was performed simultaneously

☐ The results of both assessments were used to determine the needed cost and schedule reserves

☐ These reserve numbers were compared to the initial reserve estimates and an informed decision was made – THE BASELINE WAS ESTABLISHED
RESERVE JUSTIFICATION

Cost Reserve Justification

Assumptions
- Desired reserve is 10-20% (based on historical data).
- Cost and risk estimates are accurate and complete as of the time of this analysis.
- All planned work has an estimated cost and is identified in the schedule.
- Total project costs are estimated to be $X,XXXK.

Basis
- Cost is directly proportional to the cost of resources and the duration of the task.
- Certain indirect, travel, material, facility, test support, and level-of-effort costs are fixed.
- There are widely varying levels of risk associated with different tasks.

Analysis
- The project was evaluated as a whole and each section was analyzed independently.
- A combined approach is recommended to ascertain the most accurate results.
- At a project level, an 80% level of confidence can be obtained for $X,XXXK.
- This represents a reserve of $XXXK for estimate uncertainty.

Schedule Reserve Justification

Assumptions
- Desired reserve is approximately 20% (based on historical data).
- Schedule and risk data is accurate and complete as of the time of this analysis.
- All planned work is identified in the schedule.

Basis
- Task duration is 2 years and 7 months.
- Project start is assumed to be 1/1/04 for the purpose of this exercise.
- Scheduled project completion date with 120 days of reserve is 1/2/07.
- The last unit is scheduled to ship on 7/18/06. This is the completion date without reserve.

Analysis
- To an 80% level of confidence, the project will be complete by 10/24/06.
- The difference between 7/18/06 and 10/24/06 is 72 working days of reserve, or about 9.3%.
- Recommend adding an additional 9.3% for unknown or unrealized risks.
- A total schedule reserve of between 120 to 150 days, or about 18-20% should be adequate.

Cost Probability Table

<table>
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<tr>
<th>Prob</th>
<th>Cost</th>
<th>Prob</th>
<th>Cost</th>
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11th run - revised CS FTE and other costs

- Using mean data, the table below represents recommended additions to the reserve.

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<th>Element</th>
<th>Description</th>
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<th>Mean Cost ($K)</th>
<th>Recommended Reserve Add ($K)</th>
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<td>L5</td>
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- The basis for fixed costs is not valid, therefore it is recommended that an additional 5% be allotted to cover these costs (based on the schedule reserve analysis).

Reserve Build Up

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<th>Sk</th>
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<tr>
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<td>Fixed Costs variation</td>
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TOTAL RESERVE | $XXX |

Project Estimate | $XXX |

Total Project Cost | $XXX |

Completion Date

Wed 7/26/06
Fri 9/29/06
Tue 11/16/07

11th run - revised CS FTE and other costs
IT ALL COMES TOGETHER

- The result – a time-phased and costed plan with built-in performance measurement capability
  - Time = Schedule – Our schedule tool provided a complete list of all activities required to complete our scope of work, arranged in a logical, sequential fashion, along with the capability to assess the impact on our completion date due to changes (scope, sequence, risk materialization)
  - Dollars = Estimates – By assigning costed resources to schedule activities, we had a cost plan that not only indicated total costs, but when those costs would be incurred, along with the impact of changes (scope, sequence, risk materialization)
  - Performance = Work Accomplished – The baseline contained the record of our commitment to perform work for a specified cost during a specified time period, which could then be used to compare with actual costs and actual time as the project moved forward (this also provided us with a tool to enable forecasts of time and cost for future work planned)
Key Questions Answered

“How long will it take?”

Along with key project milestone times...
IT ALL COMES TOGETHER

Key Questions Answered

“How much will it cost?”

Answer - $X M

1. Risk Assessment

2. Build Up (Estimate + Risk)
Key Questions Answered

“What’s the critical path?”

Answer – See graphic

...and goes thru Project Completion
IT ALL COMES TOGETHER

Key Questions Answered

"What resources are required and when?"

Answer – See graphic

By resource…

% Work Allocated: 4% 6% 7% 18% 22% 22% 10% 5% 7% 2% 2% 2% 2% 4% 7% 8% 10% 10%
Key Questions Answered

"What if ....?"

Answer – Using a copy of the schedule, change sequencing or durations or risk factors and analyze the outcome...

1. If I change a task's duration, or sequence, or risk factor...
2. What impact does that have on this milestone & ...
3. How does this change affect my project completion date, resource & cost phasing?
IT ALL COMES TOGETHER

☐ Changes in work scope create a “data cascade”
  ☐ The WBS is updated
  ☐ The WBS Dictionary is updated
  ☐ The Schedule is updated
  ☐ Estimates are updated
  ☐ The Risk Log is updated
  ☐ A new cost/schedule risk assessment is performed
  ☐ Reserves (cost &/or schedule) adjusted accordingly

☐ A change in any of the following creates a similar ripple effect
  ☐ Schedule – actual versus planned durations, revised plans
  ☐ Cost – rate differences, resource expenditures
  ☐ Technical – design issues, technology development issues
  ☐ Risk – retirement of risks, new risks, evolving risks
IT ALL COMES TOGETHER

☐ One key to successfully managing the project – A DISCIPLINED SYSTEM OF PROCESSES
  ☐ Management Philosophy – “plan the work, work the plan” approach
  ☐ Configuration Control (WBS, WBS Dictionary, etc.)
  ☐ Data Management (cost, schedule, etc.)

☐ Another key - COMMUNICATION !!! Is there an ECHO in here?
  ☐ An “ECHO” implies repetition – necessary part of effectiveness
  ☐ Early – gives stakeholders the most precious commodity (TIME)
  ☐ Clearly – ensures understanding and commonality of purpose
  ☐ Honestly – fosters teamwork and trust
  ☐ Often – makes certain the message is received & understood
  ☐ Openly – eliminates fear and builds the information power base

☐ Historical Note – this “package” was “bought” by our customers with only minor comments
LESSONS LEARNED (1 of 3)

- "Lock in" the WBS before proceeding with schedule, cost, or risk efforts – this will save much grief and wasted effort later on.

- Establish rigorous configuration & data management processes as early as possible – define the "data cascade".

- Don't trust your memory – write EVERYTHING down (agreements, definitions, information, etc.).

- It is extremely difficult (if not impossible) to separate estimating durations and making people-resource allocations – each has a bearing on the other.

- Have the people doing the work involved in planning the work – they know more about it than anyone else.

- Decide which TPM's you will use, on which tasks, and document them during the planning process.

- Cost and schedule should tell the same story from different perspectives with the same ending.
LESSONS LEARNED (2 of 3)

- Cost and schedule inputs are related – some are serial (such as resource use), some are parallel (resource & indirect rates)
- It always takes more than you think (money, time, & resources) – unproductive costs are a reality, be prepared
- Indirect costs are real and may double (or more) the total cost of your project – be prepared for this reality
- Schedule, cost, and technical risks are related – but are not necessarily always directly proportional
- Historical data is very valuable – USE IT! – chances are, someone else paid very dearly for it
- When using historical data, ensure you understand its context, especially in relation to your own
LESSONS LEARNED (3 of 3)

There is no such thing as a project too large or too small to benefit from good integrated project management practices — the best practices are those that are consistent in ideology but scalable in practice (i.e., they can shrink or grow to fit the circumstances).