Tollgate Project Management Process:
- Define tollgates and checklist items to be completed for each tollgate
- Project reviews are based on checklist items at each tollgate

Example Discussion:
The example on the next page shows a 10-tollgate template.
- The number of tollgates used can be changed.
- For this example items 1-6 correspond to “Defining the problem and Formulating solutions”, plus numerous project management tasks.
- Tollgates 7, 8 and 9 correspond to “detailed design and development”
- Tollgate 10 covers field support, a very important component of a real-world product development project

Chart supplied by Terry Russell, OU ME Advisory Board Chairman
Mission: Develop and certify by December 1999 the GE-P&W Engine Alliance GP7000 engine for the 747-600 airplane with airplane certification by December 2000 to satisfy our customers and shareholders with world class products and services.

Strategize
- Identify mission
- Gather market intelligence
- Establish Senior Leadership Team
- Identify Leadership Team
- Establish NPI Team
- Evaluate business impact
- Define initial program requirements
- Conceptual designs evaluated
- Tollgate 1 checklist reviewed completed.

Get Consensus
- Define key technical requirements
- Establish risk assessment criteria
- Hold conceptual design & program planning cross-functional reviews
- Finalize alternative approaches (strategy)
- Identify manufacturing approaches
- Perform risk assessment
- Selling price established, target cost reviewed, current capability cost defined
- Prepare preliminary program plan
- Tollgate 2 checklist reviewed completed.

Design
- Expand team membership
- Begin risk assessment plans
- Generate preliminary approach
- Obtain stakeholder feedback and revise approach as needed
- Vendor partners identified
- Identify installation impacts
- Customer study deck complete
- Engine operability & deterioration requirements defined
- Detailed maintenance cost rolled up
- Earn share acceptance of design
- Confirm all technologies on hand
- Review Tollgate 3 checklist
- Conduct Tollgate 3 review

Tollgate Completion Schedule
<table>
<thead>
<tr>
<th>(9/17/96)</th>
<th>(9/30/96)</th>
<th>(10/18/96)</th>
<th>(11/30/96)</th>
<th>(12/9/96)</th>
<th>(12/18/96)</th>
<th>(1/10/97)</th>
<th>(3/31/97)</th>
<th>(9/97)</th>
<th>(4/98)</th>
<th>(12/00)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>GE</td>
<td>GE</td>
<td>GE</td>
<td>GE</td>
<td>GE</td>
<td>GE</td>
<td>GE</td>
<td>GE</td>
<td>GE</td>
<td>GE</td>
<td>GE</td>
</tr>
<tr>
<td>GP7000</td>
<td>GP7000</td>
<td>GP7000</td>
<td>GP7000</td>
<td>GP7000</td>
<td>GP7000</td>
<td>GP7000</td>
<td>GP7000</td>
<td>GP7000</td>
<td>GP7000</td>
<td>GP7000</td>
</tr>
</tbody>
</table>

Validate
- Tech Regime established
- Performance stack up complete
- ICD approved
- Design stack up complete
- Preliminary Type Board held
- Certified Qualification plan reviewed
- Design certification defined
- Finalize design
- Finalize manufacturing processes
- Identify design review & program scorecard schedule
- Identify Review Tollgate 6 checklist
- Conduct Tollgate 6 review

Develop
- Complete component tests, engine, and flight testing as required
- Final complete component testing as required
- Finalize detailed test hardware
- Prepare test hardware
- Review Tollgate 7 checklist
- Conduct Tollgate 7 review

Produce & Support
- Review productivity data
- Review field data
- Identify ongoing improvements
- Hold periodic Tollgate 8 reviews
- Review Tollgate 8 checklist
- Conduct Tollgate 8 review

Percent Overall NPI Program Complete

Percent Tollgate Checklist Items Complete

Mission: Develop and certify by December 1999 the GE-P&W Engine Alliance GP7000 engine for the 747-600 airplane with airplane certification by December 2000 to satisfy our customers and shareholders with world class products and services.

GE Aircraft Engines

GE Proprietary Information Unauthorized Reproduction Prohibited
Close up view of Design through production tollgates

(9/97) 7 Design
+ Launch program.
+ Refine critical path elements/schedule.
+ Identify CTQ's.
+ Initiate concurrent detail design & manufacturing process planning.
+ Hold detailed design reviews.
+ Finalize detail design/test definition.
+ Review Tollgate 7 checklist.
+ Conduct Tollgate 7 review.

(4/98) 8 Develop
+ Procure/manufacture hardware.
+ Validate process capability.
+ Finalize detailed cert/qual test plans.
+ Prepare test hardware.
+ Review Tollgate 8 checklist.
+ Conduct Tollgate 8 review.

(12/99) 9 Validate
+ Complete component tests, engine, and flight testing as required.
+ Confirm all program requirements are met, and complete documentation.
+ Obtain customer/agency approval.
+ Review Tollgate 9 checklist.
+ Conduct Tollgate 9 review.

(12/00) 10 Produce & Support
+ Review producibility data.
+ Review field data.
+ Identify ongoing improvements.
+ Hold periodic Tollgate 10 reviews.

Chart supplied by Terry Russell, OU ME Advisory Board Chairman
Sr. Design Tollgates

1. Tollgate 1 – Conceptual and Preliminary Design
   a. Sufficient problem definition, development of design specifications, and investigation of alternatives
   b. Sufficient/correct analysis of alternatives
   c. Sufficient justification provided for selection of “best” design concept
   d. Sufficient/correct development of preliminary design to show feasibility with respect to ability to meet design specifications
   e. Sufficient project management planning and scheduling has been completed
Sr. Design Tollgates

Tollgate 2 – Experimental prototyping, testing, simulation, analysis, and system-level design refinement

a. Fully developed **hardware configuration** based on sufficient/correct prototyping, testing, analysis and simulation

   · Appropriate types/methods of analysis & simulation were used; parameters in simulations were based on experimental data for the actual system; analysis & simulations were completed correctly and documented well.

   · Appropriate prototypes were built and experiments were based on a clear need for information; experiments were designed, planned, and conducted well; data was analyzed correctly and the process was documented well.

b. Design methods (DFX, FMEA, Value Engineering,….) were used appropriately and applied correctly to refine/improve the design
Sr. Design Tollgates

Tollgate 3 – Design refinement and performance validation via prototype testing

a. Prototype performance shows that final design can adequately meet all critical design specifications

b. Performance predictions from dynamic simulations correlated/compared to actual performance results and all significant discrepancies corrected

c. Adequate cost/manufacturability analysis has been completed
Sr. Design Tollgates

Tollgate 4: Pre-Production Review

a. Final design includes refinements based on prototype testing and simulations

b. Final design characteristics (dimensions, materials, etc.) have been developed based on failure analysis with respect to all potential failure modes, and proper design factors of safety were achieved

c. Project documentation package is completed, including a complete and correct set of properly dimensioned and toleranced engineering drawings

d. Final design has been evaluated for form/fit/function, manufacturability, assembly, safety, reliability, cost, patent infringement, and environmental impact, and results of these evaluations are clearly documented
Sr. Design Tollgates

For all tollgates:

a. The design report and formal presentation associated with each design review must be acceptable

b. All group members must exhibit sufficient mastery of the “Professional Skills and Tools” associated with the current phase of the design process
Notes on Proceeding From Preliminary to Final Design

Preliminary Design
A preliminary design defines
1 Basic configuration (how things fit together)
2 Sizing (scale) of the system (realistic bounds on values for key design parameters)
3 Possible/reasonable alternatives for design components
4 Basic functions and how they will be provided/satisfied by the design

Creating and Gathering Information/Embodiment Design/Design Refinement
To progress from a preliminary design to a final design requires information
This information comes from the analysis and testing that you do to create and evaluate your design
• Prototyping and testing
• Research
• Simulation and Analysis
• Application of Design Methods to simplify/modify/improve design
Most decisions must be made before we have all of the information we would like to have
• One challenge is learning to deal with uncertainty and still make good and timely decisions

Final Design
A “near-optimal” (or at least acceptable) final design requires
• Definition of nominal values and tolerances for all design parameters
• Sizing/selection of mechanical elements to
  o Satisfy requirements for form/fit/function
  o Avoid common failure modes
  o Address important design issues