Engineering Stages of New Product Development

Criteria and common language to know where you stand in bringing innovations from conception to market

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INTRODUCTION

Confident that the definitions will serve their purpose of aiding the DOE/NIST Energy-Related Inventions Program (ERIP) management, the Task Group also dedicates its report to effective communications among inventors, engineers, entrepreneurs, corporate managers and others involved in new product development. The "Engineering Stages of Development" is a distinct concept formulated by the Task Group to serve the principal task at hand: to provide criteria for use in determining the development status of a new product or process development project and to provide a uniform language for use in describing the engineering work remaining to be done. The definitions of the Engineering Stages of Development, therefore, identify generic engineering data and information needed to determine whether a new product or process development project should proceed from stage to stage. Consequently, the definitions should serve various aspects of new product development management generally, as well as their intended uses supporting the ERIP. Those uses are elaborated in the text of this report.

GLOSSARY A
DoD STAGES OF DEVELOPMENT

Research (6.1)—"Includes all effort of scientific study and experimentation directed toward increasing knowledge and understanding in those fields of the physical, engineering, environmental and life sciences related to long-term national security needs." All "research" programs are included in the technology base budget activity.

Exploratory Development (6.2)—Efforts directed toward evaluating the feasibility of proposed solutions to specific military problems. Includes both applied research and development of "breadboard hardware." All exploratory development programs are included in the technology base budget activity.

Advanced Technology Development (6.3A)—Programs that explore "alternatives and concepts prior to development of specific weapon systems." Includes development of hardware and feasibility demonstrations for technologies that "are not formally identified to specific operational requirements." All advanced technology development programs are in the advanced development research category.

Advanced Development (6.3A and B)—Programs that have begun development of hardware for test. Purpose of efforts in this category relate primarily to "proof of design" rather than development of hardware for use. All programs in the advanced technology development budget activity, and some programs in the strategic, tactical, intelligence and communications and defense-wide mission support budget activities are in the advanced development research category. Advanced development programs move from advanced technology development into the strategic, tactical, intelligence and communications or defense-wide mission support activity after they have been selected by the Defense Acquisition Board as programs that are to move from advanced development to engineering development, and eventually to production. This selection, known as a "Milestone I decision," takes place during advanced development.

Engineering Development (6.4)—Programs that develop hardware for military use according to specifications established by the services. Excludes development of systems already approved for production. Programs move from advanced development to engineering development when they are selected in a "Milestone II decision" by the Defense Acquisition Board. Engineering development programs are found in the strategic, tactical, intelligence and communications and defense-wide mission support budget activities.

Management and Support (6.5)—Includes research and development efforts directed toward support of installations or operations required for general research and development use. Includes would-be test ranges, military construction, maintenance support of laboratories, operations and maintenance of test aircraft and ships, and studies and analyses.

GLOSSARY B
TERMS FOR DEFINITION OF STAGES

bench or breadboard models—These models are one level of sophistication higher than the test-of-principle (TOP) model. These models are used to prove that a new product, which might be developed from a scientific concept, will perform as expected and provide data to prove same. Bench models refer to chemical processes while breadboard models refer to products.

commercial introduction plan—This plan should discuss in detail the cost to build and operate a manufacturing facility or process plant and turn a profit in the marketplace with a competitively priced product. The engineer's responsibility is to pencil out the cost of manufacturing a new product and assist the marketing staff in long-range projections of the cost per unit volume or for a mass-produced product.

development plans—Produced during the technical feasibility stage, this plan precedes the development stage. It speaks up front to any potential show-stoppers to be considered along with some preliminary cost estimates of manufacturing or producing the new product. Finally, the estimate cost and time schedule for development must be delineated.

engineering activities—Used in describing the engineering activities required in each stage of development. These engineering activities must be completed to mark a discrete endpoint of each stage during the evolution of a new product.

Engineering information—The engineering information is that information derived by performing the engineering activities required to complete the stage of develop- ment. This information can be presented to aid decision makers in identifying the end of a stage.

engineering prototype—An actual working version of a product system or process which is used to gather engineering information on the operation, performance to specifications and manufacturing requirements. Most often it is one of a kind and commonly fitted with special instrumentation. The model is usually handmade, but of sufficient technical quality to determine whether a preproduction prototype can (or should) be built.

preproduction prototype—A full-scale, completely operational model designed and built to determine production and fabrication requirements for the production of the new product/process. This prototype is used to generate preproduction engineering data and information on the operation and quality and reliability of the preproduction model. The preproduction prototype should adhere to commercial design standards for the final full-scale production product or process.

product—The word product is used in the more global sense to refer to structures, machines, systems, processes, software or technical services.

prototype—A prototype can be a mock-up, model or actual working version of a technological device or process. Prototypes are used to generate engineering information that will help design or perfect the final product/process. Engineering prototypes, test-of-principle models, bench models, breadboard models and preproduction prototypes are used in the new product stage of development.

scientifically valid—Scientifically valid means there are no general truths or physical laws, as obtained and tested through the use of the scientific method, that do or could render the concept infeasible.

state of the art—An engineering term normally implying the state of knowledge available in a field of science or engineering. This is often derived from either a survey of the open scientific literature or, in the case of products/ processes, a patent search of inventions in the general subject area can be useful proof. The purpose is not to reinvent the wheel and to avoid patent infringement battles at a later date of product development.

test-of-principle models—Test-of-Principle (TOP) models are used when one is not sure how a concept will work and when one feels it would be too costly or difficult to model adequately on a computer. One can use as much ingenuity in designing a cheap and dirty but adequate TOP model as in designing the product/process. The TOP model is often less than full scale, inexpensively and crudely constructed and need not function optimally. It is a reduction to practice, proof of concept. It may not even have to look like the real thing if, in your understanding, it tests the principle one needs to test. For more details on TOP models, see “Successful Engineering,” by Kamm, McGraw-Hill, 1989, p. 176.

TASK GROUP OBJECTIVES FOR ENGINEERING STAGES OF NEW PRODUCT DEVELOPMENT

The Engineering Approach to New Product Stages of Development

The definition of the stages of development for new products has been elucidated many times before the formation of this particular Task Group (1, 2, 3, 4 and Glossary A: DoD Stages of Development). The stages have been defined from both business/marketing and engineering perspectives. But those efforts lacked major input from a broad spectrum of engineering disciplines. Therefore, the NIST/NSPE Task Group was established to provide this engineering input.

It was the Task Group's initial intent to address only the engineering aspects of product development. As work progressed, the group decided it was necessary to alert the user of the definitions to the many business and marketing aspects of product development as well.

The makeup of the group was unique in that it consisted of engineers representing many different aspects of product development—education, research, invention, marketing, production, manufacturing and management. The group's objective was to outline a set of definitions that were clear, brief and descriptive enough to identify the stage or stages through which a new product passes.

What is an "engineering stage of development"? The Task Group agreed upon the following definition:

An Engineering Stage of Development is a period during which designated engineering activities are completed. The end of a stage is an optimum decision point in the progression toward realization of a product, process or service. The objective of each stage is to establish the engineering information (technical, economic and risk assessment) necessary to make the decision to proceed or not.

Throughout the definitions, the term "Stages of Development" refers to "Engineering Stages of Development."

The Universe of the New Product

The Task Group took a very broad view of the universe of a new product. It included, in addition to the traditional new product definition, areas of electronic systems, new chemical processes, technical services and computer software. The text of the definitions often refers to "products" in the more global sense of products, processes, systems, software and services. Both evolutionary and revolutionary products are addressed in the definitions.

The group agreed that both low-technology and high-technology products should be considered as part of the definition task. It might be necessary to apply the definitions with some flexibility and relax them at times to accommodate exceptions to the rules. The Task Group may have been overambitious in taking this wide a scope for the definitions, but it wished to cover as large a universe of products related to the engineering disciplines as possible.

Risks, a Reason for Definition of Stages

Financial costs increase considerably as a product matues from concept to full-scale production. These increasing costs are suggested by Finkin (Ref. 5) in Table 1, while methods of evaluating new product risks are discussed by Abetti (Ref. 6).

Table 1

Comparative Expenditure on a New Product

Stage of Development	Cost
• Conception	$5,000
• Feasibility	$50,000 (Depending on industry)
• Product/process development	20 x Cost of Feasibility
• Pilot production	20 x Cost of Development
• Full commercialization	Much More

One of the main engineering challenges is to reduce technical risks as the product or process matures. New Product Development is a process of risk reduction. This is not to say that it is the sole function, but it is a necessary one.

The new product matures from the Conceptual Stage with its concurrent high technical risk and small financial investment through to the Large-Scale Production Stage with reduced technical risk and a much larger financial requirement.

Table 1 makes it clear that identifying a new product as clearly as possible in its development can be critical to a financial investor, project-funding agency or a corporate manager.

Engineering vs. Business Actitivies

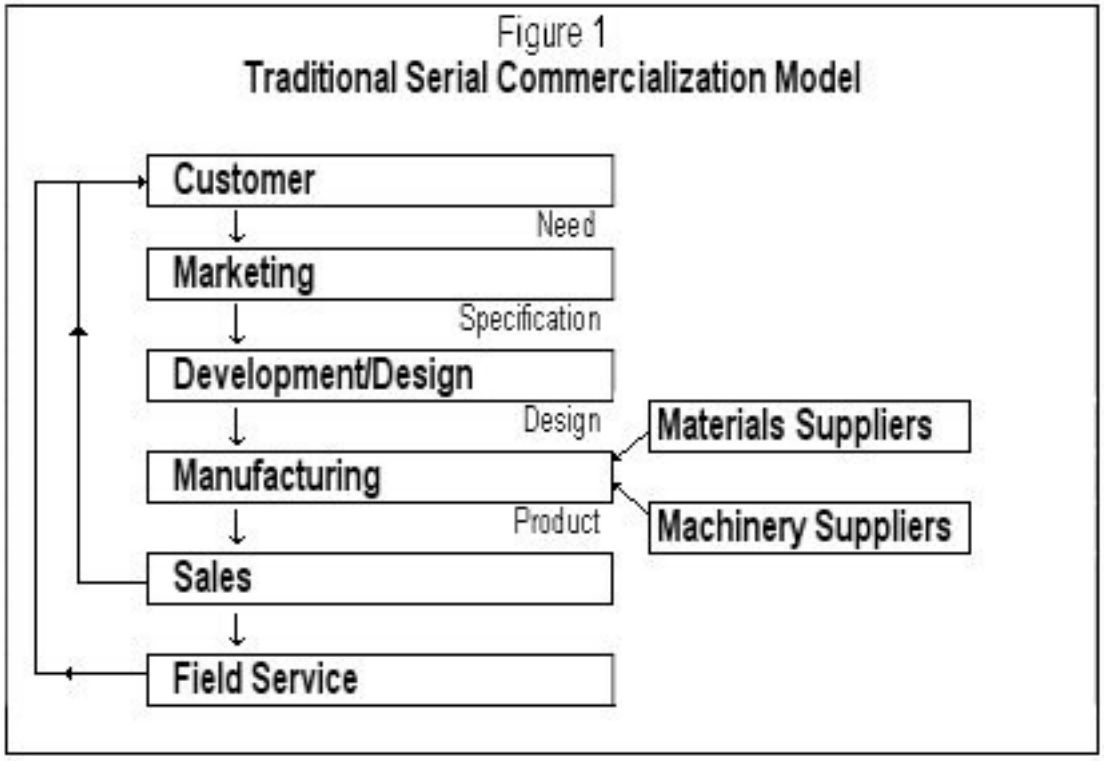
The Task Group agreed early that engineering and business-related activities occur along parallel and often overlapping paths. Even though the group originally set out to define the engineering stages separate from business decisions, it became clear that attention must be given to certain business- related questions as the stages were defined.

Serial vs. Simultaneous Engineering Approaches for New Product Development

Both serial and simultaneous engineering approaches to new product development were addressed by the group as the stages were defined. In either case the individual stages of development occur serially.

In traditional product development, a serial approach is one in which both the engineering and business specialties contribute in a serial or linear fashion as illustrated in Figure 1. In fact, in many such instances the engineering specialist is brought on board at the proper time to complete only a single stage of development. His or her advice and consultation are often not called on either before or after that serial point in the stages of development. It is for this reason that some products fail.

Figure 1
Traditional Serial Commercialization Model



In the more modern simultaneous approach, the completion of each engineering stage of development is a composite of the achievements of several engineering and business specialties. For example, manufacturing and development/design might both be involved at the same time in completing the Technical Feasibility stage of development. This might be motivated by a desire for economy in the upcoming Production stage of development. Figure 2 is a more detailed representation of the interplay of several specialties toward the completion of a given stage and, eventually, through several stages, completion of the product itself. The influence on the earlier stages may be made by scientific or engineering specialties, whereas in later stages more manufacturing and business specialties will be required (Fig. 3).

Today, it is common in larger companies to accomplish simultaneous engineering by the formulation of a multi-specialty team. The smaller business or individual inventory should consider the need for independent consultant specialists even in the earlier stages. The Task Group recognized that the location of an affordable and qualified expert is often a challenge.

Even though the Task Group recognized the simultaneous and possible overlap of activities in the stages, this does not detract from the logical serial ordering of the stages of development. It still holds that all activities should be addressed and satisfied before a stage is deemed to be complete. How an inventor weaves in and out of the stages and still satisfies their requirements is influenced to a great extent by the environment in which the development is carried out.

Figure 2

Formulation of Multi-Specialty Project Team Designed To Accomplish Simultaneous Engineering in the Stages

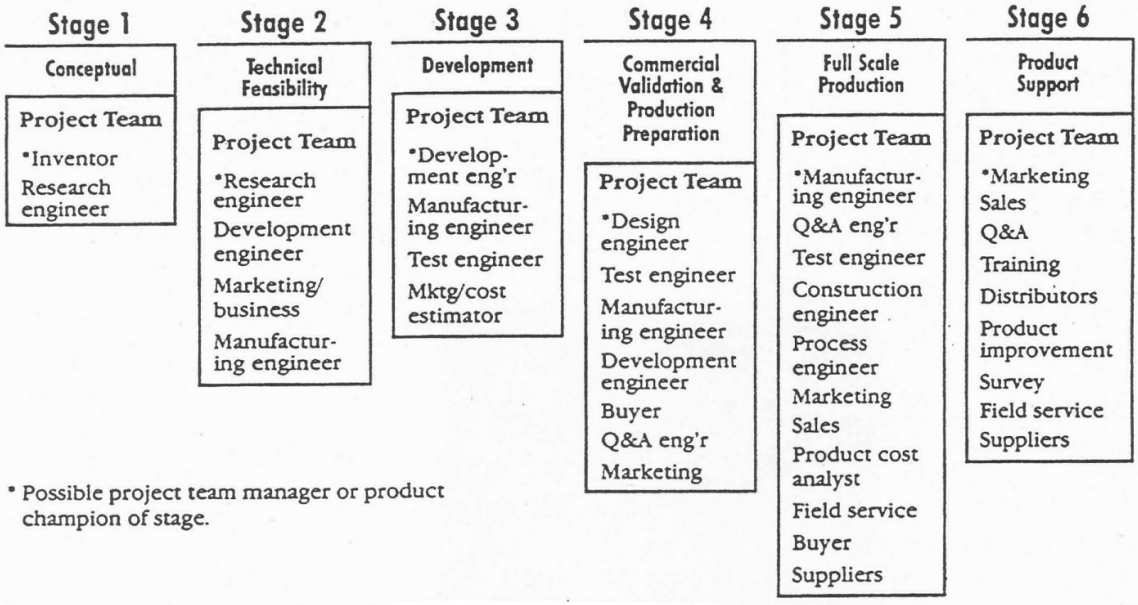
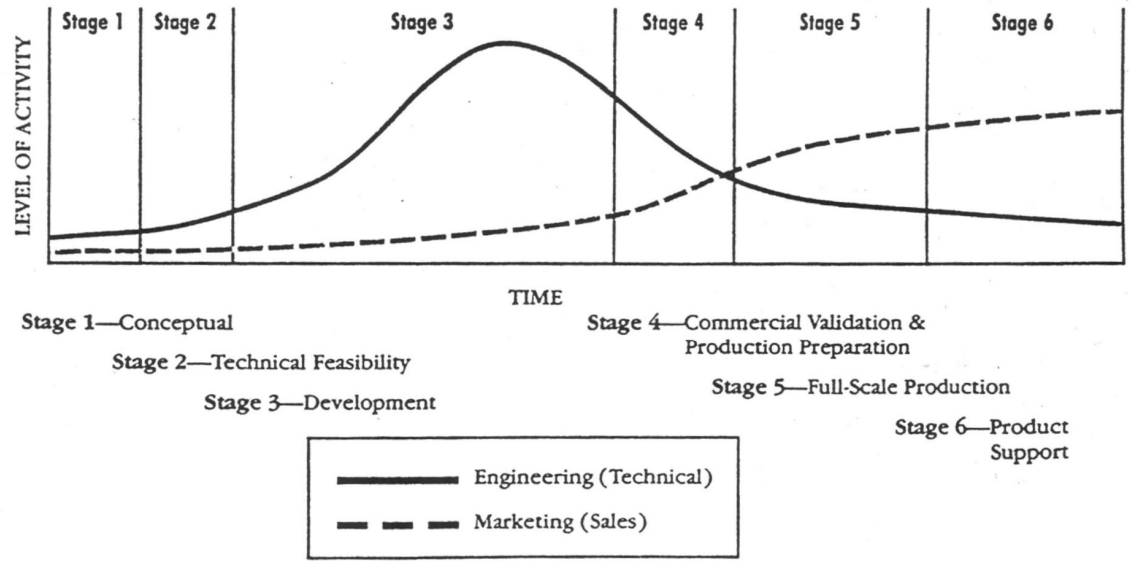


Figure 3



Need for Examples

These definitions could be made more useful and would reach a much larger audience if expanded into a textbook or a training manual with a considerably expanded syllabus using these core definitions as a framework. Eventually, their use in an engineering training curriculum might be of greatest value. This laudable expansion of the idea and its suggested application, even though beyond the Task Group's scope, deserves some comments.

Specific examples of new product development case histories are required in order to illustrate the stages of development. Examples of various hardware, processes, technical services and software development need to be set down as historical examples. A good start along these lines are case briefs on successful products discussed in a report by the Conference Board in 1986 (Ref. 7) and a book by Ketteringham in 1986 (Ref. 8). Case briefs on products from Xerography to 3M's "Post-It" are noted in a summary fashion. Other such descriptions can be found in References 9 and 10. However, more specific information is required to describe in detail how products evolve through the stages of development. Tracking a number of products, both winners and losers, through the development stages is recommended for engineering Master's theses projects. These in-depth engineering case studies would serve to test the validity of definitions for the stages of development. The Task Group highly encourages NIST to identify the most successful DOE/ERIP projects in each of the following areas: products, processes, software, services and systems. Summarizing these as case study examples vis-à-vis the "stages of development" definitions would be a useful and productive educational aid.

The Creative Process

The Task Group did not define the creative or inventive process that leads to the conceptualization stage. This is not to say that the creative process is unimportant.

In fact, just the opposite is true. However, an in-depth discussion of the characteristics of the creative or inventive process was considered beyond the scope of the present Task Group.

Format of the Definitions

The Task Group decided it was important and necessary at the beginning of each stage to describe the objective and resulting product of that stage and then proceed to outline the engineering activities that need to be accomplished in order to complete a stage of development. At the end of each stage, the user should be able to check off significant engineering data and information required to satisfy completion of the stage. The stages of development are laid out in this general format for the user.

Uses of the Engineering Stages of Development

There are various conceptions of the new product development process, none enjoying general acceptance and each varying in the activities included or emphasized. The lack of uniform, authoritative delineation and definition of the stages of new product development is seen as an impediment to communications, not only among the participants in ERIP, the Task Group's immediate concern, but among those involved in the industrial innovative process generally. The need assumes increasing importance as government and private efforts to accelerate the rate at which new technologies are applied in commercial products and processes are stepped up in order to help redress the loss of U.S. competitiveness.

The definitions of Engineering Stages of Development are intended to fulfill this need, insofar as providing engineering data and information are concerned. They are offered not only for the improvements they are expected to effect in managing the DOE/NIST ERIP, but also as an addition to the language of new product development managers. Their purpose is to enhance communications across both intramural and institutional lines. In this role, the definitions should benefit both large corporations and small businesses as they participate in collaborative efforts, such as industry-university work in the Engineering Research Centers fostered by the National Science Foundation and research consortia under the National Cooperative Research Act. Similarly, the definitions will undoubtedly be applied to good advantage in government-private programs, in addition to the DOE ERIP, fostering the commercialization of technology by providing support to inventors and small businesses.

The definitions are also expected to serve industry by enhancing internal cross-discipline communications among engineers and others involved in new product development as well as by improving external communications. The definitions should become a valuable tool for working with customers and suppliers alike as emphasis continues on reducing the new product development cycle and improving product quality.

Under the DOE/NIST ERIP, inventors and small businesses may receive technical and financial support in bringing energy-saving ideas to the market. Projects may be submitted during any stage of their development to NIST, which evaluates them and recommends those it finds technically feasible and likely to have commercial success to DOE. Upon making a recommendation, NIST provides guidance on development requirements, and, for those projects it accepts, DOE develops a statement of work in collaboration with the applicant that describes what will be done with support provided under the ERIP Program.

The development status of a product weighs heavily in the assessment of its technical feasibility and commercial viability because uncertainty and risk vary as development advances. Further, the stage of development of a product must be commonly understood by all of the ERIP Program participants, i.e., the new applicants, NIST evaluator engineers and the consultants they employ and the DOE coordinator. There is a clear need for criteria for establishing the stage of development and for a uniform language describing he engineering work required to advance to the next stage. In addition, the ordering of the stages of development under well-defined formulations provides a basis for tracking the progress of projects and evaluating the program's effectiveness and will serve other management purposes. Until the present, the ERIP Program has lacked such formulations. Projects were classified under a set of undefined terms taken from systems engineering terminology common in the defense industry in the 1960's.

As to the definitions' uses under the ERIP, the Task Group consulted George P. Lewett, Director of the NIST ERIP. The remainder of this discussion is based upon that consultation.

The definitions of the Engineering Stages of Development, therefore, will enable:

- Applicants to more effectively present data, facilitating evaluation of projects;
- NIST evaluators and consultants to better develop guidance on what engineering work needs to be done next;
- NIST to restructure the evaluation process to better consider risks and other criteria as they vary by stage of development;
- DOE, at the time a project is recommended, to document the project's stage of development in order to determine support requirements;
- DOE to better track the results of funding and other support of development efforts;
- NIST to better support reporting and other management functions: statistics, outreach performance, etc.

Documentation at the time a project is recommended may entail on-site use of the definitions. A qualified engineer, armed with the definitions, might visit the development facility and review hardware and all relevant data and documentation. He or she would then apply the definitions in documenting the development status of the project.

This application suggests a way in which the definitions may serve other public and private programs designed to foster the commercialization of technology. The definitions could be used to "certify" the stage in which a candidate project resides. Certification of the stage of development and satisfaction of completion of the engineering requirements by a qualified engineer not associated with the development project would provide an objective evaluation and basis for decision by the prospective government sponsor or a private investor. It could be a factor in the decision of whether to recommend the project to receive financial or technical support for further product development. This application of the definitions would be particularly valuable where the decision-maker does not otherwise have the technical resources required for an evaluation.

In addition to using the definitions to aid management of the ERIP, NIST will apply them in most states to programs that are designed to assist small businesses in new technology development and commercialization. Many of these programs are staffed by persons having non-technical backgrounds. The definitions, therefore, will be used in education and training seminars and workshops, conducted by local assistance centers, to upgrade staffs, as well as to improve small business capabilities for new product development. The definitions may be of additional value in enhancing communications among those studying and measuring the progress of technology development, transfer and management.

ENGINEERING STAGES OF DEVELOPMENT*

An Engineering Stage of Development is a period during which designated engineering activities are practiced. The end of a stage is an optimum decision point in the progression toward realization of a product, process or service. The objective of each stage is to establish the engineering information (technical, economic and risk assessment) necessary to make the decision to proceed or not.

*From this point forward, the more general term New Product Stages of Development will be used. It is important to note that these are defined from the engineer's perspective.

STAGE 1 - CONCEPTUAL

Definition

The conceptual stage of engineering development is that period during which a concept is proven **scientifically valid*** or is shown to be potentially valid by the application of a **test-of-principle model(s).**

Objective

The objective of this stage is to demonstrate through test or analyses the performance and implementation potential of a concept.

Engineering Activities

The **engineering activities** common to this stage are those necessary to describe an innovation, identify its potential utility and demonstrate its potential for achieving performance and implementation.

During the conceptual stage at least the following activities must be completed:

- Fully articulate the concept;
- Confirm that critical assumptions upon which the performance is founded are reasonable;
- Identify and assess critical manufacturing and marketing barriers insofar as possible;
- Conduct a **state-of-the-art** survey.

Engineering Information

The completion of the activities common to the conceptual stage of development will usually result in the following engineering information:

- A description of the concept including sketches, drawings and/or model(s);
- A target set of performance specifications or achievement goals for the concept;
- A presentation of test results or data where necessary;
- A preliminary identification and discussion of the potential barriers to development, manufacturing and marketing of a new product**;
- A statement of how the concept will be used as a new product (s).

*__Boldface type__ indicates terms defined in the glossary.

**The term "product" will be used often to refer to products, processes, systems, software and services.

STAGE 2 - TECHNICAL FEASIBILITY

Definition

The technical feasibility stage of engineering development is that period during which it is proven possible within the technological state of the art to produce a new product from the concept.

Objective

The objective of this stage is to confirm the target performance of the new product through experimentation and/or accepted engineering analysis and to ascertain that there are no technical or economic barriers to implementation that cannot be overcome by development.

Product

The usual product of this stage is a **bench or breadboard model.** Where it is not realistic to produce an entire model, feasibility must be demonstrated through an appropriate combination of tests of materials, full or partial product or process models or by other acceptable engineering techniques (e.g., computer simulations).

Engineering Activities

During the technical feasibility stage at least the following activities must be completed:

- Test for technical feasibility;
- Examine the operational requirements;
- Identify potential safety or environmental hazards;
- Make a preliminary production feasibility assessment;
- Make a preliminary manufacturing assessment.

Engineering Information

The completion of activities common to the technical feasibility stage of development will usually result in the following **engineering information**:

- Performance data obtained from actual bench or breadboard level model(s);
- Preliminary product or process designs;
- Preliminary **development plans**, where appropriate, might include the following considerations:
  - --Cost estimates of the product or process,
  - --Potential marketing strategy,
  - --Safety/environmental concerns,
  - --Preliminary manufacturing or production plans;
- Preliminary plans for the next stage, product development, shall be presented, including a cost and time schedule.

STAGE 3 - DEVELOPMENT

Definition The development stage of engineering development is that period during which the needed improvements in materials, processes and design are made and during which the product is tested and proven to be commercially producible.

Objective The objective of this stage is to make the needed improvements in materials, designs and processes and to confirm that the product will perform as specified by constructing and testing **engineering prototypes** or pilot processes.

Product The product of this stage is a tested or proven engineering prototype or pilot process.

Engineering Activities During the developmental stage at least the following activities must be completed:

- Identify critical materials and develop components and manufac- turing or process steps to the extent required to meet technical performance and economic objectives;
- Conduct the tests of critical materials, components and process steps;
- Design and fabricate a pilot process or engineering prototype suitable for scaling up in a later stage;
- Optimize the product through design iterations using computer models or other acceptable analyses and tests;
- Conduct final tests after engineering optimization and modifications.

Engineering Information The completion of the activities common to the development stage will usually result in the following engineering information:

- Proof that performance specifications are met by presenting per- formance data on the working model, **prototype**, pilot process or their components;
- A description of the potential manufacturing methods, listing critical materials and processes that are required;
- A description of the operational safety and environmental factors that may influence the final product;
- Proof of expected reliability of the product;
- Refined marketing strategy with particular attention paid to cost estimates for future large-scale production.

STAGE 4 - COMMERCIAL VALIDATON AND PRODUCTION PREPARATION

Definition The commercial validation and production preparation stage of engineering development is that period during which a product or process is prepared for introduction into the marketplace.

Objective

The objective of this stage is to develop the manufacturing techniques and establish test market validity of the new product.

Product

The product of this stage is the **preproduction prototype** or process.

Engineering Activities

During the commercial validation and production preparation stage, at least the following activities must take place:

- Complete a preproduction prototype;
- Determine the preproduction process;
- Select manufacturing procedures and equipment;
- Demonstrate effectiveness and completeness of the following:
  - -- Final product or process design and performance,
  - -- Installation and start-up plans for the manufacturing process,
  - -- Selection of production tools and technology,
  - -- Selection of materials, components and subsystem vendors and logistics,
  - -- Testing of product or process market acceptance;
- Design a field support system.

Engineering analysis data and information developed during this stage should contribute to a comprehensive **commercial introduction plan**. In order to achieve this goal the scale, quality and reliability of these activities should be representative of commercial operations. The costs of the manufacturable prototype or process should permit production of sufficient quantities for market trials of the new product or process.

Engineering Information

The completion of activities common to the commercial validation and production preparation stage of development will usually result in the following engineering information:

- Product or process performance data based on the manufacturable prototype or production level process;
- Data on maintainability and reliability;
- Data on manufacturing and production;
- List of materials, components or subsystem suppliers;

- Plans for spare parts production and availability;
- Installation and operation cost data;
- Updated operating safety and environmental safety data;
- Updated test market characteristics and data;
- Warranty and service plans.

Commercial market validation is accomplished by attention to and discussion of the following:

- Confirming acceptable manufacturing techniques and time/cost projections;
- Confirming installation within acceptable time and cost constraints;
- Operability achievable under full-scale production;
- Compliance with health, safety and other applicable industry standards;
- Productability and performances by means of appropriate tests.

STAGE 5 - FULL-SCALE PRODUCTION

Definition

The full-scale production stage of engineering development is the period during which the manufacturing or process facility is built and full-scale production runs are made.

Objective

The objective of the full-scale production stage is to put the new product(s) into commercial production and optimize the manufacturing process consistent with the market demands.

Product

The product of this stage is a market-ready product that has been frozen with respect to major design changes.

Engineering Activities

All the activities in this stage result in production maturity of the product, minimizing the need for later extensive modifications.

During the initial phase of the full-scale production stage, there is substantial investment in completion of the following activities:

- Prepare final commercial level designs;
- Detail the manufacturing process;
- Finalize quality control procedures for all levels of procurement, manufacturing and assembly or production;
- Finalize the distribution system, including shipment, warehousing and customer assistance process;
- Construct manufacturing facilities—equip and ready for commer- cial operation;
- Make trial runs of the plant under full-production conditions.

During subsequent phases of the full-scale production stage, the following activities must be continuously ongoing:

- Minor evolutionary modifications of the production process or procedures might be undertaken for the following reasons:
  - -- To enhance product function,
  - -- To reduce product cost,
  - -- To improve product quality and reliability,
  - -- To improve customer acceptance of the product.
- The need for extensive modifications requiring reentry into previous stages should be examined.

Engineering Information

The completion of activities common to the full-scale production stage of development will usually result in the following engineering information:

- Production/product drawings and/or schematics;
- Manufacturing or production flow charts;
- Production material lists, specifications and prices for raw materials;
- Operational manuals on the production process;
- Quality control and reliability standards with supporting documentation;
- Final market acceptance survey based on pilot runs or prototype tests;
- Identification of the distribution plan and customer assistance plans;
- A report on the early production test runs describing production rates, quality and associated engineering problems that need to be addressed in this stage.

STAGE 6 - PRODUCT SUPPORT

Definition

The product support stage of engineering development is the period during which the product or process realizes a useful life.

Objective

The objective of this stage of development is to maintain maximum value of the product or process through continued consideration of engineering improvement.

Product

The product of this stage is an optimum, competitive product.

Engineering Activities

During the product support stage at least the following activities must be practiced:

- Provide on-site technical instructions and updates for safe and effective use of the product or process;
- Prepare, distribute and encourage use of instruction manuals for the assembly, operation and maintenance of the product or process;
- Design, produce and distribute “consumables” used in the product or process;
- Design and introduce timely but minor improvements in materials, components, systems and software;
- Produce and distribute spare parts;
- Set up and provide warranty services;
- Introduce new applications developed for the product or process;
- Identify new product spin-offs or major product design changes that would require going back into earlier stages to be reidentified as a new product;
- Disseminate alerts and undertake remedial action for unplanned product deficiencies or changing safety and environmental requirements.

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