# The Turbojet Engine Model of R&D Management

M.E.Glinsky, D. DePledge, J. Straccia, G. Davis and D. Nevelsteen

## I. Executive Summary

A model for R&D management based on the analogy of a turbojet engine is presented. The goal is to use a system to manage our R&D that is as advanced as the R&D that we do. There are four guiding principles to the design of this system: simplicity, freedom, responsibility, and auditability.

The engine is divided into five stages: the intake, the compressor, the combustion chamber, the nozzle and turbo-charger, and the thruster and feedback controller. The intake, through a managed and coordinated process identifies technologies from internal R&D organization, business units, universities, marketing organizations, competitive intelligence, national laboratories, and project spin-offs. The compressor is a map of business units and business drivers to levers that technology projects can pull. This will allow for flexibility and quality control in determining the business value of technology. The combustion chamber is where technology meets business need creating business value, the ultimate goal. Technology projects are associated with levers, targets for those technology projects are set, costs and timing specified, deliverables stated, probability of success determined, and options for R&D outlined. The nozzle increases the efficiency of the engine by forcing a strict tollgating procedure on the system. The tollgates are reached by meeting the deliverables within the time frame and budget specified. Projects are allowed to continue on to the next tollgate according to a ranking based on an optimization of expected monetary value, EMV, constrained by risk, cash flow and resources. There is also a mechanism via which strategic alignment can also be incorporated in a quantitative way. The final stage is the thruster. Here the technology project will be implemented and/or commercialized – the business value will start to be extracted.

This process will be governed by a Research Committee that will control the process and arbitrate disputes. There will be an alignment of behavior and the process goal (i.e., optimizing EMV with constraints) by a system of incentive compensation.

There are several things that this management model adds. The first is an auditable and refinable valuation of each technology project based on the business technology maps and technology project targets – a valuation that includes realistic financial models and risked option valuation. The second is a quantified way to determine the level of R&D funding under risk, cash flow, and resource constraints. The third is a rational way to allocate R&D funding. The fourth is quantified value to present to host governments to justify the use and funding of technology. The fifth is an alternative method of R&D cost allocation to the business units. The sixth, yet most important, is an improvement in the efficiency of R&D in creating business value and the alignment of R&D with the corporate strategy.

## II. Overview of the Turbojet Engine

The analogy that we use to develop the model of R&D management is that of a high-performance turbojet engine (see Fig. 1). The goal is to use a system to manage our R&D that is as advanced as the R&D that we do.

There are several guiding principles to the design of this engine. The first is simplicity. The process should be easy to understand. The simplicity will also prevent manipulation of the process that defeats the goal of maximizing the efficiency of the money spent on R&D. This simplicity should also be manifest in as little process overhead and burden on the researchers as possible.

The second is freedom. Teams and managers should be trusted to make the right decisions. Only at well-defined tollgates will there be an audit. This freedom to operate between tollgates will have an ancillary benefit of allowing a further optimization of the process.

The third is responsibility. Researchers and the people that oversee the process should be held responsible for their actions and decisions. This starts by designing a process where the value added by teams and individuals are quantified. It continues by linking the compensation of the teams and individuals by how much value they create. By aligning the motivation of teams and individuals with the goals of the R&D organization, the process controls can be simplified and freedom to optimize the process maintained.

The fourth is auditability. By requiring that targets are set and predictions of success are made, not only can the expected value of the R&D be calculated and used to control the process, a measurement can be made of the quality of those targets and predictions. This measurement can be used to improve the quality of the targets and predictions in the future. The result will be a more efficient process.

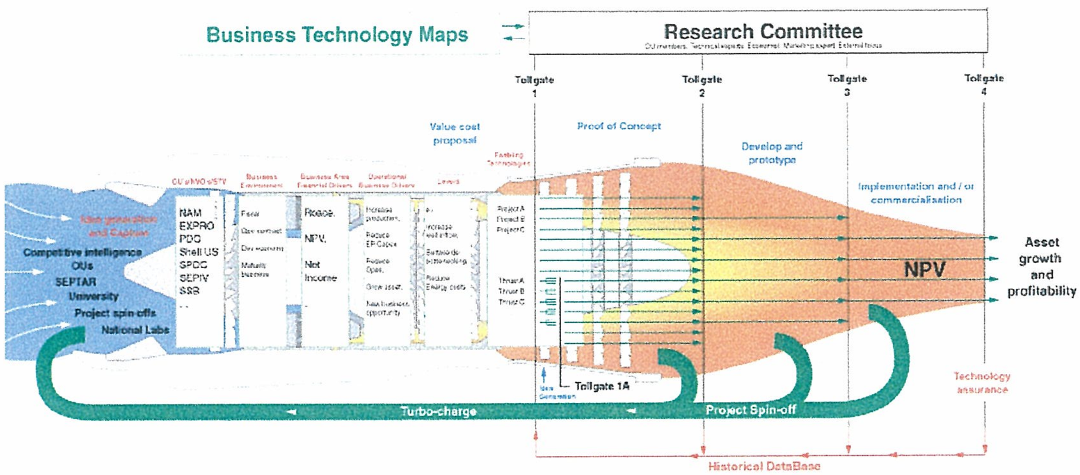


Figure 1. Schematic of the Turbojet Engine Model of R&D Management.

## III. The Individual Stages of the Turbojet Engine

There are five stages to the turbojet engine: the intake, the compressor, the combustion chamber, the nozzle and turbo-charger, the thruster and feedback controller. Each one of these stages will be described and details of how they function are now presented.

### A. Intake

The intake is designed to be an efficient collector of quality ideas - the air without which the engine would cease to function. This is a managed and coordinated process that has many sources of ideas. It is powered, as all of the stages, by an incentive compensation scheme (see Appendix 2).

The researchers will be empowered to search for ideas, with a modest budget (approximately one man month). This budget can be used to cover their time, fund external work, or pay for expenses. They will be compensated for each qualified idea that they generate. These ideas will be databased and quality controlled to eliminate duplication and frivolous ideas. The rules attached to spending this money should be the absolute minimum. The alignment of motivation and behavior will be relied upon to govern the behavior. This alignment of motivation and behavior will be a reoccurring theme in the overall process.

There will also be focused workshops and thrust areas. These efforts will be determined by the identified dangling levers, which will be discussed more fully in Sec. IIIB. Alignment with dangling levers will also be used as a criteria to fund external work. Funding of external work and interaction with the external world is an important part of this intake mechanism. This will allow us to identify promising scientific advancements before other R&D organizations and to find out the commercial value of the advancements, as well as file patents, before our competitors. Some external work will be funded through the budget made available to individual researchers, but there needs to be a larger source that is centrally managed.

The source of ideas will be the internal R&D organization, business units, universities, marketing organizations, competitive intelligence, national laboratories, and project spin-offs.

The funding for this effort should be a healthy fixed amount for the first few years, then allowed to float to its equilibrium level. This equilibrium level will be approached as a capital allocation (portfolio) decision.

The cost value proposition will determine this equilibrium level. A major input to the proposition will be the probability of success of these efforts. Because of how important this number is to the proposition and how important the intake is to the functioning of the tubo-jet engine, we have recommended the healthy fixed level until enough historical data can be collected to accurately determine the probability of success.

There will need to be a small group that will manage this process. Their function will be to determine which ideas are new and profound (i.e., worthy of compensation), database those ideas, organize thrust areas, and manage funding of external efforts.

This process places large emphasis on external sources of technology project ideas and puts in place a process to determine the optimum funding level for those external sources.

**B. Compressor**

The compressor concentrates the air supplied by the intake (ideas) by identifying the ways in which it can add value to our business. This is done by constructing the business part of the business technology maps.

The Business Technology Maps (BTMs) are a mapping of business units to business environments to financial drivers to operational drivers to levers to enabling technology projects. This mapping allows a flexible analysis and quality control of the process. An example of the flexibility is subtracting or adding business units as our business portfolio changes and examining the implication of the changes on our technology project portfolio. An example of the quality control of the process will be summing potential impacts of all technologies to ensure that the total impact of technology will be consistent with historical norms.

The process via which the business part of the BTMs are constructed starts by collecting information from the group economists on the business environment, business areas, financial drivers, operational drivers, barrel breakdowns, productions targets, cost targets, tax regime, and equity ownership. The business units will be welcome to supply this information, but as much use of the centrally located economists, as the business units feel comfortable, will be made. This is to reduce the data supply burden on the business units. A group of Technology Marketing Managers (TMMs) will then visit the business units once a year to define the business levers and their dependencies. Another group called the Research Committee will have the ability to challenge and modify the levers and their dependencies. The TMMs will have ownership of the BTMs. They will be posted on the web for challenge and for use as the process continues.

A few more words need to be said about the Research Committee. It is a group of 15 to 20 people. They are the body controlling the entire process and are the supreme court, arbitrating disputes in the system. In addition, they will have many more responsibilities outlined in later sections. They will meet once a month and be made up of business experts (senior business unit representatives), marketing experts (commercialization and implementation specialists), technical experts, economists, and external focus specialists. All of the members can revolve in and out as needs dictate. There will be a chair of this committee who will manage and plan the meetings, and will have responsibility for making sure that all necessary information is collected for making the decisions. This committee will be crucial to the process functioning well, and will meet for a week each month.

The compressor provides an auditable way to identify levers with business drivers and business value.

**C. Combustion Chamber**

The combustion chamber is where the air (technical ideas) meets the fuel (business levers) and ignite and generate the energy (business value). There is a two step process to constructing this value cost proposal. First, the researchers propose technology projects that will pull the business levers. They also set technology project targets for how much the levers will be pulled. Second, the TMMs go back to the business units to determine the applicability of these technologies.

The preparation of the research proposal will be owned by a research team conductor (RTC)[1]. Whenever a person or group of people have come up with a promising notional idea, the Research Committee will assign a RTC from an available pool. A RTC will be assigned multiple projects. It will be the responsibility of the RTC to arbitrate team disputes, to make sure that the proper resources and personnel are available to accomplish the project objectives, to prepare the research proposal, and to be the advocate for the project. The RTC will receive incentive compensation based on whether the projects they conduct meet their expected probability of success.

The research proposal will contain: an executive summary, a one page technology project description, a list of business levers which it could pull, the technology project targets of how much it will be able to pull those levers, buyup/maintain/buydown option, description of tollgate deliverables, cost estimates by tollgate, time estimates by tollgate, resource estimates by tollgate, possibilities for outsourcing at each phase of the research, description of competitive landscape, dependencies upon other projects, and test area if the project makes it to prototyping phase. The estimates of costs, resources, times will have minimum, maximum, and most likely. Deviation of targets, costs, resources, and times for historical average values will have to be justified. The structure of the tollgates will be described in the next section.

A project can pull more than one lever. It can also create its own branch of levers starting at any level of the BTM. This includes creating its own business unit if it will lead to a new business opportunity. This creation of new branches should be welcomed since it indicates innovation, that is, out-of-the-box thinking.

Since a lever may be pulled by more than one project, it should be determined by the TMMs, during their visit to the business units, whether the projects will have a complimentary effect or an exclusive effect.

The buyup option will consist of an alternate research plan that will increase the applicability of the technology project and/or decrease the time to implementation if more money is spent on the project. The buydown option is the opposite. The farmout option means different things at different tollgates. At the earlier tollgates, it could be contracting university, private research laboratories, petroleum service organizations, or national laboratories to do the proof-of-concept and/or development of a prototype. At the latter tollgate, it is commercialization. The farmin option is doing it internally. Things that should be captured in the definition of the farmout option should be the direct costs, cost of supervision, cost of loss of core competency, cost of internalization of results, time to next tollgate, and the availability of needed infrastructure. Detailed information only needs to be given for the next tollgate. Only an indication of whether the farmout option will exist for later tollgates should be given. The RTC will facilitate the discussion leading to the creation of these options.

The business units will be able to challenge the technology project targets, costs and timing. The researchers and RTCs will be able to challenge the applicability and the complimentary/exclusive determination of the TMMs. These challenges will be arbitrated by the research committee. The research proposals along with the business technology maps will be kept on the web.

The probability of success for the next phase of the research will be determined by a secret ballot of the research committee. They will vote on which bin of probability (0-10%,10-25%, 25-50%,50-75%,75-100%) the project falls. Probability of success for subsequent phases will be historical averages.

The targets that are set in the combustion chamber form the basis for calculating the asset based value add. There is also a structure for a fair and proper challenge of the value add. The R&D options outlined will allow for more flexibility in the system and increase the efficiency of R&D in creating business value.

**D. Nozzle and Turbo Charger**

The nozzle increases the momentum of the gas (technologies) thereby increasing the thrust (EMV) generated by the turbojet engine. The momentum of the gas is increased by a strict tollgating procedure controlled by the research committee. The turbo charger also increases the thrust of the engine by recirculating spinoff ideas and premature technologies back into the air intake.

The tollgating procedure starts by ranking the projects according to a maximization of the expected monetary value (EMV) with constraints on risk, cash flow, and resources (discussed in Appendix 1)[2,3]. A further modification to the ranking can be made to align it with the E&P strategy (discussed in Appendix 3). An overall funding level is determined by the point at which the risked value investment ratio (RVIRT) of adding the next project is equal to that of investments other than technology. The subscript on RVIRT is because the investment is the R&D cost and any additional capital needed to implement the technology. Once this optimum funding level is determined, projects are funded starting at the top of the ranked list until the optimum funding level is reached. This will be applied to all projects when the turbojet engine is first started. Thereafter, it will only be applied when a project reaches a tollgate.

The project development will be broken up into five stages: initial proposal, proof of concept, develop and prototype, implementation and/or commercialization, and exit. Each phase will be divided by a tollgate where a decision will be made. Generally, there will be seven options: farmin/farmout/minimal and buyup/maintain/buydown options for the farmin and farmout options. Upon reaching a tollgate, a research proposal for funding will be made. If the project is ranked above the line for optimum funding it will be granted its next round of funding. When the project has spent the most likely funding level or the most likely time for that phase is reached, it will come under review by the research committee. Only for good cause will approximately 50% of the projects be allowed to continue. Once the maximum limits have been reached, the project will be given minimal funding for abandonment. Only in very rare cases will the project be allowed to continue at more than the minimal funding level.

Researchers will have an incentive compensation based on having project on which they are working successfully pass a tollgate. The research committee will determine when a project has successful reached a tollgate by secret ballot. The criteria will be delivery of all deliverables associated with that tollgate as specified in the research proposal. Passing the tollgate is only associated with meeting the technical deliverables. Whether or not a project will be granted its next round of funding, once it has passed the tollgate, will be a strictly financial decision described in Appendix 1.

As the technologies move into the prototype phase, the research committee should appoint a user group to oversee development. This user group should be technical people who are representative of the people who will be using the technology. The research committee should rely on their judgment of whether or not a successful prototype is made. The researchers should be encouraged to have regular contact with the user group during the development.

An additional tollgate is required for research thrusts. Research thrusts are associated with dangling levers which have no technology projects associated with them. They are identified and proposed by the group that oversees the intake process. They will be assigned a RTC and will compete for funding along with the technology projects. The difference is that they will be trying to identify technologies that could pull the dangling lever. Any technology that they identify will have to have a proposal for research funding made for it. The consideration of this proposal is the additional tollgate.

The nozzle is a procedure for strict tollgating. This tollgating ensures that the option value of the process is realized.

**E. Thruster and Feedback Controller**

The thruster is where the air reaches it highest velocity at the end of the nozzle and is where the thrust (EMV) is realized. This happens as the technology is applied to our asset base or is commercialized. We consider that the technology has left our turbojet engine when it reaches full implementation. Information on the performance of the engine (historical data) should be collected and input to the feedback controller (research committee) to optimize the performance of the engine.

Centrally resourced funding should cover establishment of infrastructure for implementation and demonstration of widespread value. This will not cover ongoing costs once the infrastructure and value is established. This funding of the ongoing costs should come from fees associated with use of the technology. The centrally resourced funding should be viewed as the last round of venture capital funding. A marketing organization, either internal or external, should be the group driving the implementation. This marketing organization will be responsible for training, sales and marketing. As the technology exits the nozzle (reaches full implementation) all control should be turned over to the marketing organization and all centrally resourced funding should be discontinued. They should directly fund cosmetic changes to the product through user fees. Major new enhancements should be input as a proposal to the turbojet engine.