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# TECHNOLOGY TRANSFER

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JPL   TECHNOLOGY TRANSFER DEFINITION

• THE TRANSFER OF ORGANIZED KNOWLEDGE TO A PROJECT OR PROGRAM FOR THE EVENTUAL PURPOSE OF PRODUCING NEW OR IMPROVED, PRODUCTS, PROCESSES OR SERVICES.

• TRANSFER WILL OCCUR THROUGH ONE, OR MORE, OF THE FOLLOWING MODES:
   • OCCASIONAL CONSULTING
   • DOCUMENTATION (REPORTS, ASSESSMENTS, PROGRAMS, OR DRAWINGS)
   • TRAINING (ON-THE-JOB, ON-SITE OR ELSEWHERE)
   • DEMONSTRATION (PROOF-OF-PRINCIPLE OR APPLICATION TO A REAL-WORLD PROBLEM)
   • COLLABORATIVE TECHNICAL WORK.
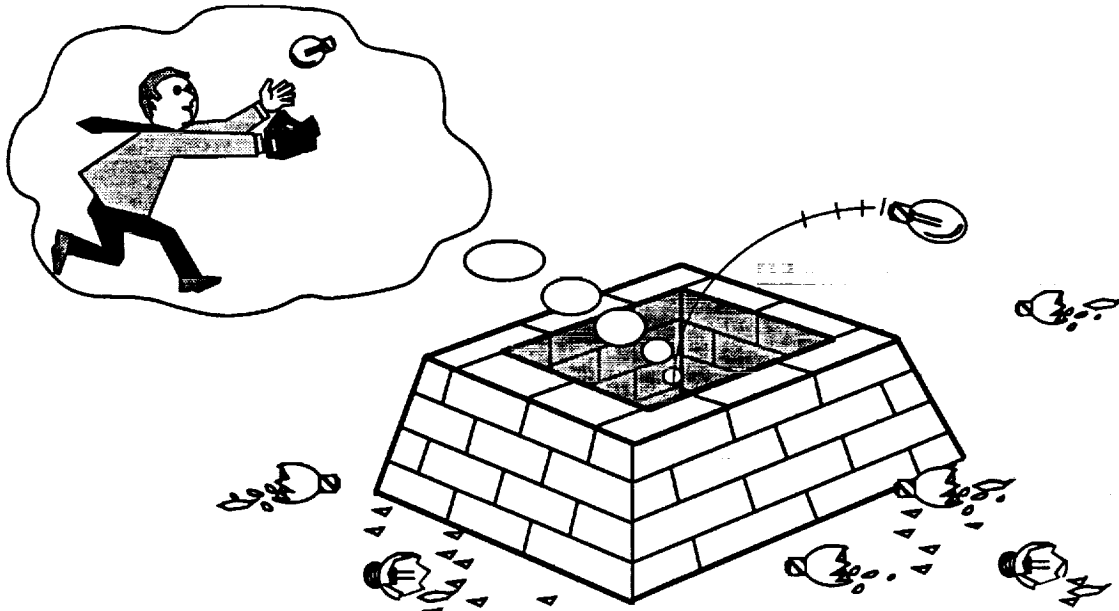
THH-1

TOO OFTEN R&D HAS BEEN CONTENT TO
'THROW ITS PRODUCT OVER THE WALL AND
HOPE SOMEONE WILL CATCH IT.'

THH-2

JPL "BOTH SIDES OF THE FENCE"

ADVANCED DEVELOPMENT	IMPLEMENTATION OR PRODUCTION
• TECHNICAL MANAGEMENT WITH ASSISTANT ENGINEERS	• PRODUCT MANUFACTURING MANAGEMENT WITH SUSTAINING ENGINEERING CORE
• WORK PERFORMED BY SPECIALISTS AND TECHNOLOGISTS	• WORK DONE BY ENGINEERS AND TRAINED PERSONNEL
• FLEXIBLE OPERATIONS AND INTERACTION	• ORGANIZED PRODUCTION
• TIGHT CONTROL POSSIBLE	• MANUFACTURING TOLERANCE NECESSARY
• SMALL THROUGHPUT AND VOLUME	• LARGE THROUGHPUT AND VOLUME
• LOW INERTIA	• HIGH INERTIA
• DEDICATED ATTENTION	• LARGE BATCH "PHILOSOPHY"
• JUDGEMENT CRITERIA	• PASS/FAIL CRITERIA
• EXTENSIVE REWORK PRACTICAL	• REWORK DISRUPTIVE, UNINTERRUPTED FLOWS, STAGING DELAYS
• FLEXIBLE EQUIPMENT	• NARROW LATITUDE, SEVERAL SHIFT CONTINUOUS OPERATIONS SYSTEMS
• LITTLE DOCUMENTATION - DATA INTENSIVE	• EXTENSIVE DOCUMENTATION - DATA/ OPERATIONS INTENSIVE
• COST NOT PRIMARY	• COST PRIMARY
• CHANGES ROUTINE, EASILY IMPLEMENTED	• CHANGES DIFFICULT TO IMPLEMENT
• REAL-TIME ANALYSIS, TRACEABILITY, AND FEEDBACK	• NON-ROUTINE ANALYSIS DIFFICULT, FEEDBACK DELAY RESULTS IN LOSSES
• QA SEPARABLE FUNCTIONS	• QA NECESSARILY INTEGRAL

THH-4

JPL IMPLICATIONS OF TECHNOLOGY MATURITY

MATURE

DRIVEN BY COST REDUCTION
PRESSURE ON MARGINS
BARRIERS TO CHANGE
ADVANTAGE TO CHALLENGERS

GROWTH

DRIVEN BY MARKET RESEARCH
PRESSURE ON SPEED
BARRIERS TO ENTRY
ADVANTAGE TO MARKET LEADER

EMERGING TECHNOLOGY

DRIVEN BY PROBLEM RESEARCH
PRESSURE ON NARROWING OPTIONS
BARRIERS TO RISK TAKING
ADVANTAGE TO ENTREPRENEUR

THH-3
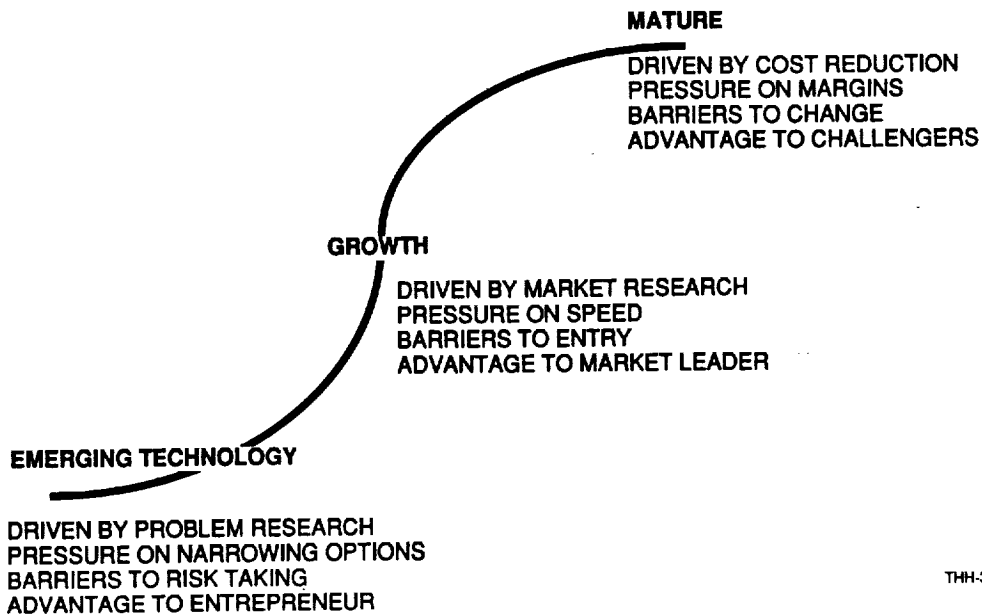
JPL SIMPLIFIED LOOK AT BOTH SIDES

ISSUE	TECHNOLOGY OR ADVANCED DEVELOPMENT	IMPLEMENTATION OR PRODUCTION
• MANAGEMENT	• TECHNICALLY ORIENTED	• PRODUCT ORIENTED
• STAFFING	• TECHNOLOGIST AND SPECIALISTS	• ENGINEERS AND PRO-DUCTION PERSONNEL
• THROUGHPUT	• SMALL	• LARGE
• INERTIA	• LOW	• HIGH
• DOCUMENTATION	• MINIMAL	• EXTENSIVE
• COST	• NOT PRIMARY	• PRIMARY

THH-5

R4-3

CULTURE OF BOTH
ORGANZIATIONS

CAPABILITY OF USER
ORGANIZATION(S)

NEEDS OF THE
USER
ORGANIZATION

CHARACTERISTICS OF
THE TECHNOLOGY

CAPABILITIES OF THE
R&D ORGANZIATION

ENABLERS/PROMOTERS

BARRIERS
TO
TECHNOLOGY
TRANSFER

TECHNOLOGIES

TRANSFER
SUCCESSES

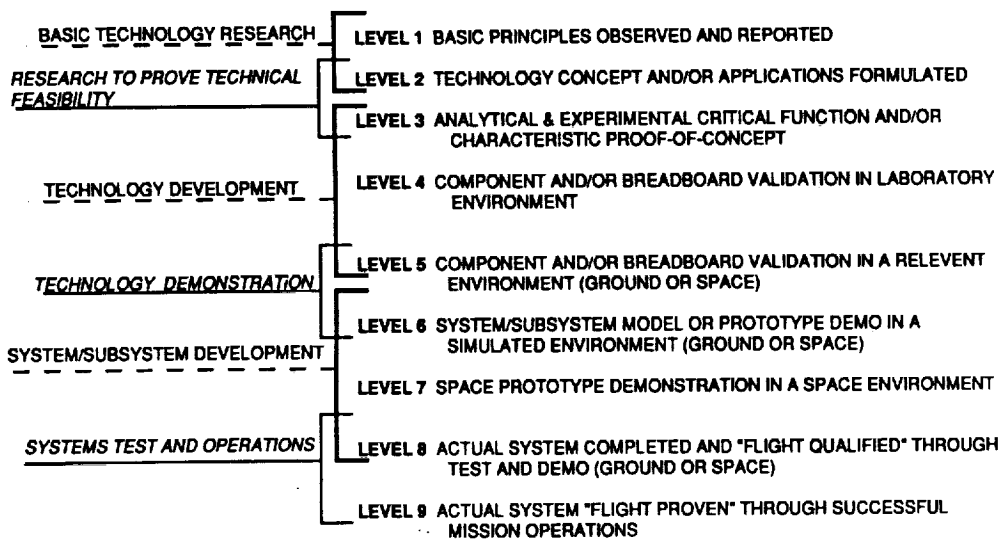TRANSFER
FAILURES

THH-6

JPL   **Barriers**

• The user community lacks a process to identify common technology requirements

• The user community lacks a vehicle to exert the collective leverage to cause JPL/NASA to implement common design.

• Resources invested in existing systems and applications, and the attitude and culture of the work force make it difficult to evolve to new technologies.

• Current practices encourage a tactical approach to solving technical problems while ignoring key strategic (i.e. long term) issues.

• There are inadequate incentives fostering the insertion of new technology in to new missions. The linkage between technology payback and achieving missions goals is not strong.

• Fear of being unable to complete a mission (on-time, within budget, and meeting mission goals) using "newer" technology.

• There is no documented, coherent JPL/NASA vision for broad-based technology integration and the role of technology transfer in achieving that vision.

THH-6a

JPL   Barriers (cont'd)

• There is no shared vision for developing a technology transfer process.

• Transfer is further complicated by the fact that oft times capabilities rather than specific products must be transferred.

• With today's projects, you cannot simultaneously accept a "fixed-priced" contract from Congress to develop a major undertaking and at the same time support technology development and the unavoidable attendant risks, i.e. cost uncertainty.

• Inadequate staffing by engineering. A common response to the suggestion for new technology is "We do not have anyone here who has the technical skills and knowledge to incorporate this technology into current projects."

• The perception that a technology is too complex will often lead the intended users to question the technology developers credibility.

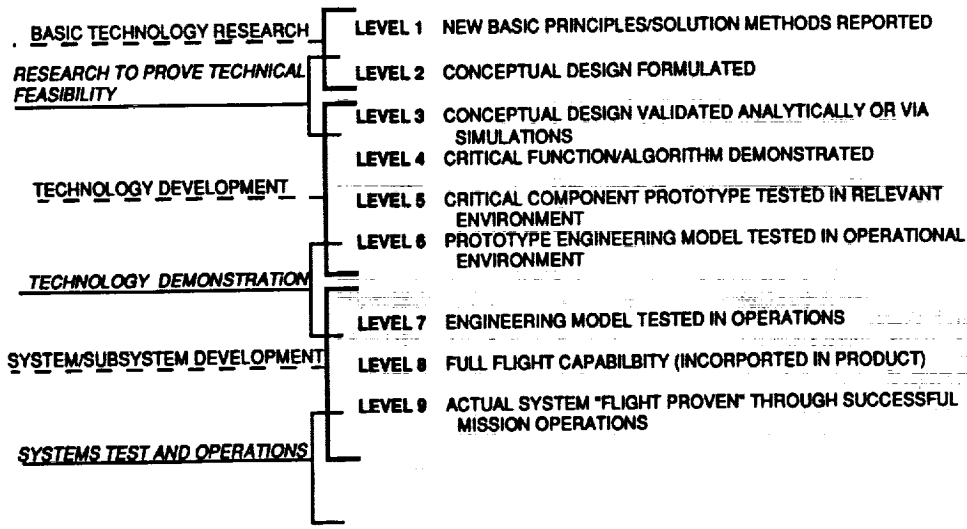• NASA does not develop serious plans beyond a five year new start horizon

THH-6b

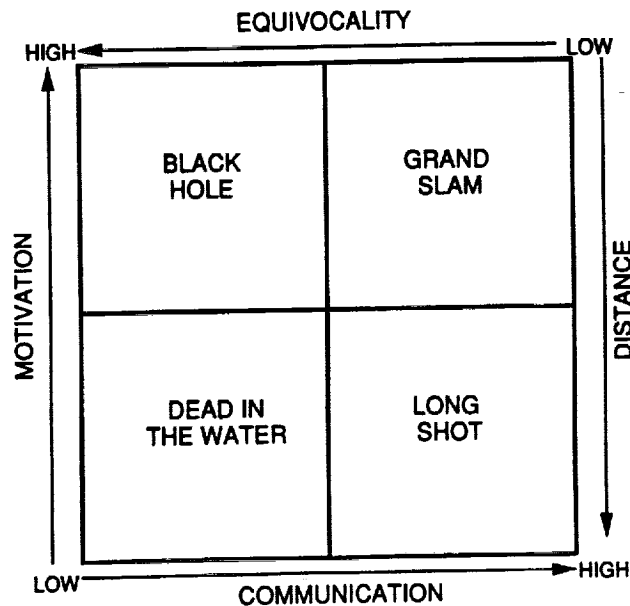# JPL TECHNOLOGY READINESS LEVELS

BASIC TECHNOLOGY RESEARCH	LEVEL 1 BASIC PRINCIPLES OBSERVED AND REPORTED
RESEARCH TO PROVE TECHNICAL FEASIBILITY	LEVEL 2 TECHNOLOGY CONCEPT AND/OR APPLICATIONS FORMULATED
	LEVEL 3 ANALYTICAL & EXPERIMENTAL CRITICAL FUNCTION AND/OR CHARACTERISTIC PROOF-OF-CONCEPT
TECHNOLOGY DEVELOPMENT	LEVEL 4 COMPONENT AND/OR BREADBOARD VALIDATION IN LABORATORY ENVIRONMENT
TECHNOLOGY DEMONSTRATION	LEVEL 5 COMPONENT AND/OR BREADBOARD VALIDATION IN A RELEVENT ENVIRONMENT (GROUND OR SPACE)
	LEVEL 6 SYSTEM/SUBSYSTEM MODEL OR PROTOTYPE DEMO IN A SIMULATED ENVIRONMENT (GROUND OR SPACE)
SYSTEM/SUBSYSTEM DEVELOPMENT	LEVEL 7 SPACE PROTOTYPE DEMONSTRATION IN A SPACE ENVIRONMENT
SYSTEMS TEST AND OPERATIONS	LEVEL 8 ACTUAL SYSTEM COMPLETED AND "FLIGHT QUALIFIED" THROUGH TEST AND DEMO (GROUND OR SPACE)
	LEVEL 9 ACTUAL SYSTEM "FLIGHT PROVEN" THROUGH SUCCESSFUL MISSION OPERATIONS

THH-7

R4-5

JPL SOFTWARE TECHNOLOGY READINESS LEVELS
(PROPOSED)

BASIC TECHNOLOGY RESEARCH

LEVEL 1 NEW BASIC PRINCIPLES/SOLUTION METHODS REPORTED

RESEARCH TO PROVE TECHNICAL FEASIBILITY

LEVEL 2 CONCEPTUAL DESIGN FORMULATED

LEVEL 3 CONCEPTUAL DESIGN VALIDATED ANALYTICALLY OR VIA SIMULATIONS

LEVEL 4 CRITICAL FUNCTION/ALGORITHM DEMONSTRATED

TECHNOLOGY DEVELOPMENT

LEVEL 5 CRITICAL COMPONENT PROTOTYPE TESTED IN RELEVANT ENVIRONMENT

LEVEL 6 PROTOTYPE ENGINEERING MODEL TESTED IN OPERATIONAL ENVIRONMENT

TECHNOLOGY DEMONSTRATION

LEVEL 7 ENGINEERING MODEL TESTED IN OPERATIONS

SYSTEM/SUBSYSTEM DEVELOPMENT

LEVEL 8 FULL FLIGHT CAPABILBITY (INCORPORTED IN PRODUCT)

LEVEL 9 ACTUAL SYSTEM "FLIGHT PROVEN" THROUGH SUCCESSFUL MISSION OPERATIONS

SYSTEMS TEST AND OPERATIONS

THH-8

JPL TECHNOLOGY TRANSFER MATRIX
(FROM A STUDY)

EQUIVOCALITY

HIGH ◄——————————————► LOW

BLACK HOLE	GRAND SLAM
DEAD IN THE WATER	LONG SHOT

MOTIVATION

DISTANCE

LOW ——————————————► HIGH

COMMUNICATION

THH-9

JPL WHY? - PART OF THE ANSWER IS THE CHICKEN/EGG SYNDROME

MUST HAVE:
• PROGRAM CREDIBILITY
• COST/SCHEDULE PREDICTABILITY, I.E. MATURITY

OSSA
AMBITIOUS MISSIONS NOT CONSIDERED FOR LACK OF ADVANCED TECHNOLOGY

MUST HAVE:
• TECHNOLOGY/NOT DEVELOPMENT
• JUSTIFICATION
• PRIORITY
• FUNDING

OAST
ADVANCED TECHNOLOGY NOT WORKED FOR LACK OF AMBITIOUS MISSIONS
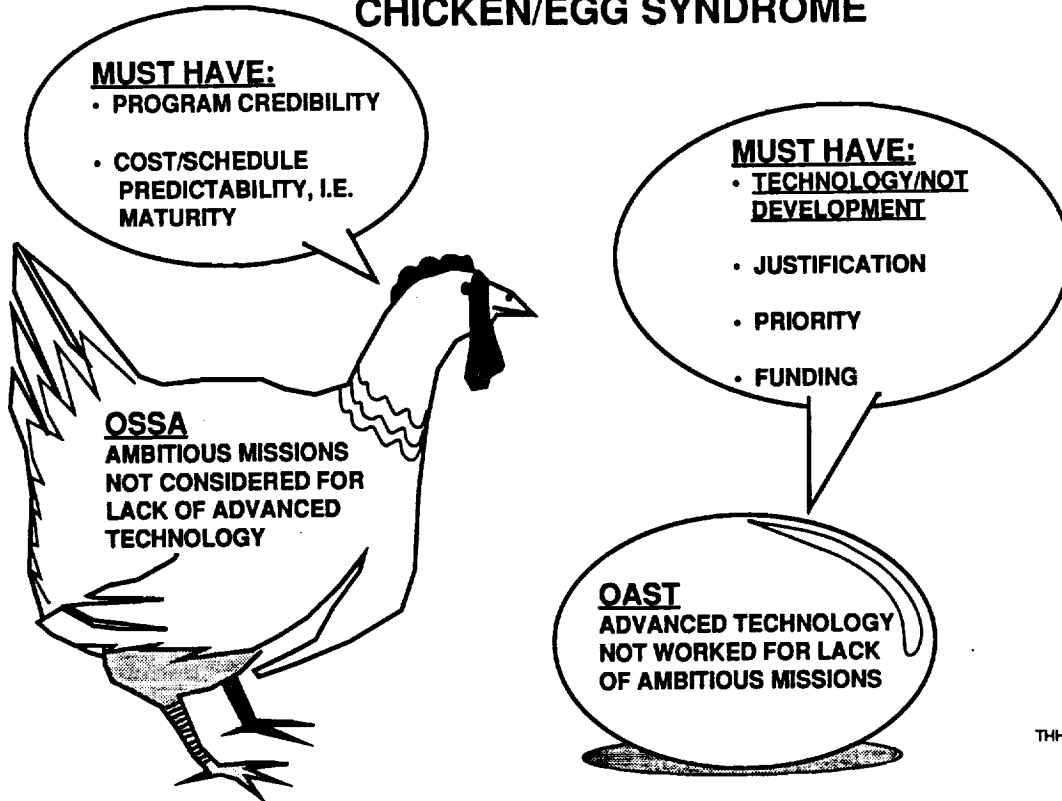
THH-10

JPL WHY? - MUTUALLY EXCLUSIVE PLANNING CRITERIA ARE PART OF THE ANSWER

I CAN'T PLAN AMBITIOUS MISSIONS, YOU DON'T HAVE DEVELOPED TECHNOLOGY!

I CAN'T DEVELOP THIS TECHNOLOGY, YOU DON'T HAVE MISSIONS THAT REQUIRE IT!

NEEDS
• PROGRAM CREDIBILITY
• COST/SCHEDULE PREDICTABILITY - MATURITY

OSSA

OAST

NEEDS
• TECHNOLOGY/ NOT DEVELOPMENT
• JUSTIFICATION
• PRIORITY
• FUNDING

THIS IMPASSE MUST BE BREACHED

THH-11

WHY? - DIFFERENT VIEWS OF TECHNOLOGY "READINESS" ARE ALSO A PROBLEM

THH-12

JPL TECHNOLOGY TRANSFER FUNDING GAP

THH-13

JPL FUNDING PROFILE DURING TECHNOLOGY TRANSFER
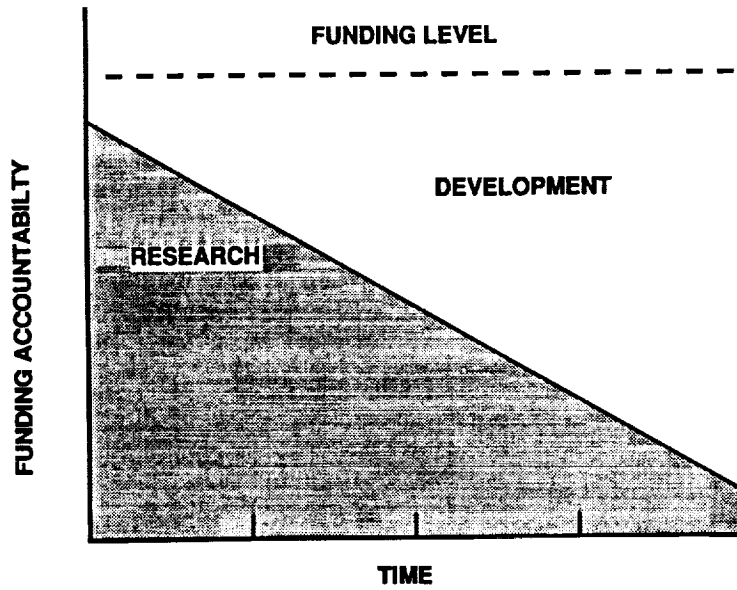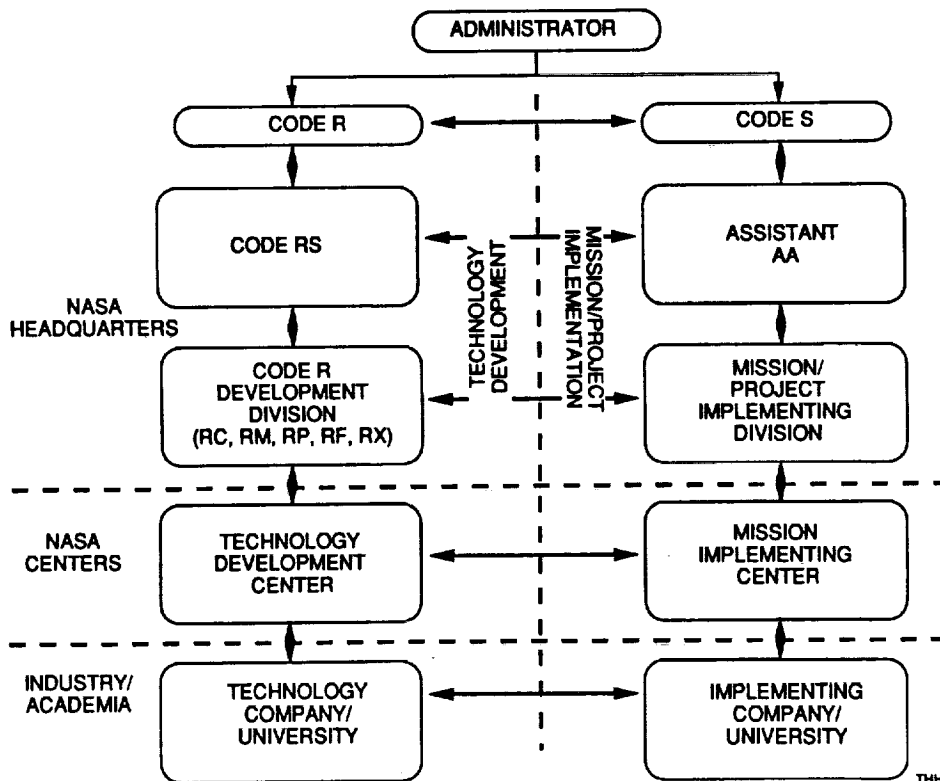
FUNDING LEVEL

DEVELOPMENT

RESEARCH

FUNDING ACCOUNTABILTY

TIME

THH-14

JPL NASA TECHNOLOGY TRANSFER INTERFACES

ADMINISTRATOR

CODE R — CODE S

NASA HEADQUARTERS

CODE RS — ASSISTANT AA

TECHNOLOGY DEVELOPMENT

MISSION/PROJECT IMPLEMENTATION

CODE R DEVELOPMENT DIVISION (RC, RM, RP, RF, RX) — MISSION/ PROJECT IMPLEMENTING DIVISION

NASA CENTERS

TECHNOLOGY DEVELOPMENT CENTER — MISSION IMPLEMENTING CENTER

INDUSTRY/ ACADEMIA

TECHNOLOGY COMPANY/ UNIVERSITY — IMPLEMENTING COMPANY/ UNIVERSITY

THH-15

R4-9

JPL   KEY FACTORS

- **PLANNING**

- **USER INVOLVEMENT**

- **COMMUNICATIONS**

- **A PROCESS IS REQUIRED**

- **KNOWING AND ASKING THE RIGHT QUESTIONS**

- **RESPONSIBILITY AND ACCOUNTABILITY**

- **FUNDING**

THH-16

JPL   TECHNOLOGY TRANSFER PROCESS

OUT-YEAR
PLAN AND SCHEDULE

NEEDS WORK

NEW
TECHNOLOGIES

ON-GOING PROGRAM

NEW
REQUIREMENTS

ANNUAL
REVIEW

ON-GOING PROGRAM

NEW PROGRAM

SELECT
ADVOCATES

TECHNOLOGY
READINESS
REVIEW

PRELIMINARY
PROGRAM
REVIEW

ANNUAL
OPERATING
CYCLE

TECHNOLOGY
TRANSFER
PLAN

RE-PLAN

UNSUCCESSFUL   86

END-USER ACCEPTANCE

= FUTURE ACTIVITY,
NEED NOT BE DONE INITIALLY

THH-17

R4-10

JPL   THE DO'S

- TREAT THE TECHNOLOGY TRANSFER AS A PERSONAL COMMITMENT. IT IS PEOPLE THAT MAKE PARTNERSHIPS WORK

- ANTICIPATE THAT IT WILL TAKE UP MANAGEMENT TIME. IF YOU CAN NOT SPEND THE TIME, DO NOT START THE TRANSFER

- MUTUAL RESPECT AND TRUST ARE ESSENTIAL. IF YOU DO NOT TRUST THE PEOPLE YOU ARE WORKING WITH, FORGET IT

- REMEMBER THAT BOTH PARTNERS MUST GET SOMETHING OUT OF IT. MUTUAL BENEFIT IS VITAL. THIS WILL PROBABLY MEAN THAT YOU HAVE GOT TO GIVE SOMETHING UP. RECOGNIZE THIS AT THE OUTSET

- DO NOT PUT OFF RESOLVING UNPLEASANT OR CONTENTIOUS ISSUES UNTIL "LATER".

THH-18

JPL   THE DO'S (contd)

- RECOGNIZE THAT DURING THE COURSE OF THE TRANSFER/COLLABORATION, CIRCUMSTANCES AND MARKETS CHANGE. RECOGNIZE YOUR PARTNER'S PROBLEMS AND BE FLEXIBLE

- MAKE SURE THAT YOU AND YOUR PARTNER HAVE MUTUAL EXPECTATIONS OF THE TRANSFER AND ITS TIME SCALE

- GET TO KNOW YOUR OPPOSITE NUMBERS AT ALL LEVELS

- APPRECIATE THE CULTURAL DIFFERENCES. DO NOT EXPECT A PARTNER TO ACT OR RESPOND IDENTICALLY TO YOU

- RECOGNIZE YOUR PARTNER'S INTERESTS AND INDEPENDENCE

THH-19

THE RDQ (RESEARCH AND DEVELOPMENT QUOTIENT) WAS ORIGINALLY
DEVELOPED BY WARREN LUSHBAUGH TO EVALUATE JPL ENGINEERS,
GROUPS, SECTIONS, ALDs...

DEFINITION:

$$RDQ = 10 \, LOG \left(\frac{\text{NUMBER OF "ATTA BOY" REQUIRED TO CANCEL}}{\text{A SINGLE "OH S..."}} \right)$$

-10	0	10	
SAND-BOX PLAYERS	ACCEPTABLE R&D	ACCEPTABLE IMPLEMENTATION	FOSSILS! OR RETIRED-IN-PLACE
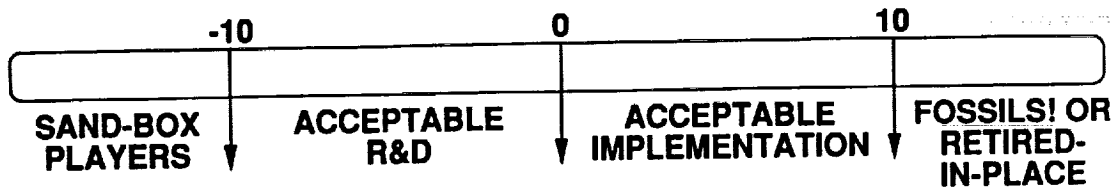
WARNING: ADJUST YOUR OBJECTIVES TO YOUR BOSS'S RDQ!

THH-20

Technology Transfer

JPL

Version 2.0
November 11, 1991

Table Of Contents

Figures and Tables

Acknowledgements

Over the course of this research effort, numerous individuals have provided valuable assistance either by reviewing the work in its various stages, or by giving information and advice. I would like particularly to thank the following individuals for their significant contribution

I make no claim that the views expressed herein are necessarily held by them, and I assume full responsibility for any mistakes that may remain.

If you have comments, questions, etc, please contact me :

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(818) 354-7009

1.0 Introduction

At its worst, traditional technology transfer is "tossing the good ideas over the wall to engineering" (see Figure 1). The ideas are not "caught" by the people on the other side; the results: missed opportunities; the technology developer is isolated from the intended user; the technology developer certainly does not know where the user is going; and the intended user does not know the new technology is coming. No wonder that these ideas are not "fielded" by the intended user.

At its best, technology transfer is the process by which both the intended user and technology developer get what they want and need. The user receives new or needed capabilities. The technologist receives recognition, continued funding, satisfaction or the like.

TOO OFTEN R&D HAS BEEN CONTENT TO
THROW ITS PRODUCT OVER THE WALL AND
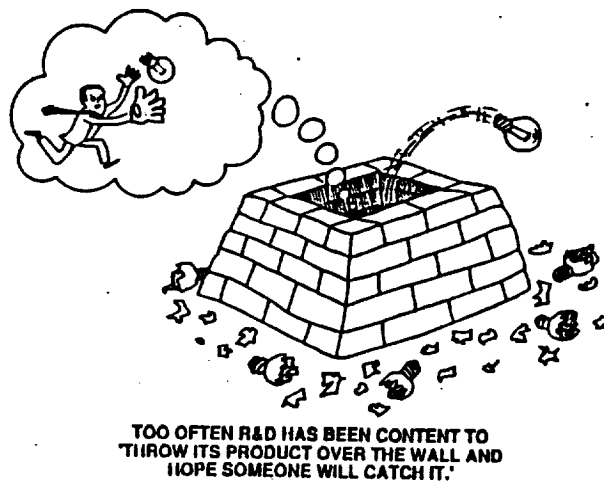HOPE SOMEONE WILL CATCH IT.'

Figure 1 Traditional Technology Transfer

It may be said, that the Space Exploration Initiative (SEI) has a planning window of today through 2025, or ten years beyond initial long-term presence on Mars. Critical to the success of these long-lived programs is the ability to remain technologically viable during this extended development and mission-operations era. When the capabilities of terrestrially deployed systems are increasing by an order of magnitude every five to ten years, computers every three to four years, and detectors every two years, what does it mean to design systems for programs that require ten years to develop and have a life expectancy of up to 35 years? There are a number of obvious options: (1) Freeze the technology and stash a lifetime of spares, (2) plan for a complete replacement every five to seven years, (3) ignore the need for change and let the future take care of itself, or (4) plan to evolve the system. Only the fourth option suits the missions' purposes.

From a JPL point of view, these decadal missions map into the need to consistently and rapidly move the results of research and development into main stream mission development. For JPL survive and prosper, upgrading of technology must be a vital part of each mission. At present, JPL's technology utilization spans a dizzying range from 1970's to 1990's technology. These are all significant drivers leading to the realization that a more formal technology transfer process is needed at JPL.

This paper will discuss the requirements for a successful technology transfer program and what such a program would look like. In particular, this paper will address the issues associated with technology transfer in general, and within the JPL environment specifically.

The balance of the paper is in two Sections, i.e. Background and Technology Transfer. Section 2, Background, will (1) set the stage, (2) identify the Barriers to successful technology transfer; and (3) suggest Actions to address the Barriers either generally or specifically. Section 3, Technology Transfer, will present a process with its supporting management plan that are required to ensure a smooth transfer process.

If the reader is interested only in the process, the Background Section may be skipped ... thus, you may proceed directly to Section 3.

2.0 Background

Technology transfer may be defined as

> the transfer of organized knowledge to a project/program for the eventual purpose of producing new or improved, products, processes or services. Transfer will occur through one, or more, of the following modes: occasional consulting, documentation (reports, assessments, programs, or drawings), training (on-the-job, on-site or elsewhere), demonstration (proof-of-principle or application to a real-world problem), and collaborative technical work.

Given this definition, it is obvious that technology transfer is absolutely dependent on person-to-person communications and is affected by all those things which encourage or inhibit communications, such as need, funding or confidence.

One important observation is that, in general, most "new" products are in fact improved versions of products that were available "last" year. They are based, not on a brand new idea from science, but on improving an existing product. And the process of repeated incremental improvement that produces these new versions of the product is inherently resistant to ideas from outside itself. Figure 2, details some of the implications of Technology Maturity. Thus, it is important to have a routine mechanism for inserting these technology improvements into the development cycle.

It does not take too many missed opportunities before both sides start losing interest in the whole process. Missed handoffs have the potential of large impacts on the projects. Thus, what we need are clear mechanisms (viz procedures, processes) with their associated management and cultural infrastructures, that enable reliable, consistent, and successful technology transfers.

Embedded within this mechanism is the recognition that the attributes, needs, etc for each of the organizations have different drivers e.g. cultural, motivation or rewards systems (see Figure 3). For example, in advanced development, documentation only need be adequate for individuals intimately involved in the technology, whereas, in implementation, documentation is paramount in the organizations ability to provide reproducible, standard products.
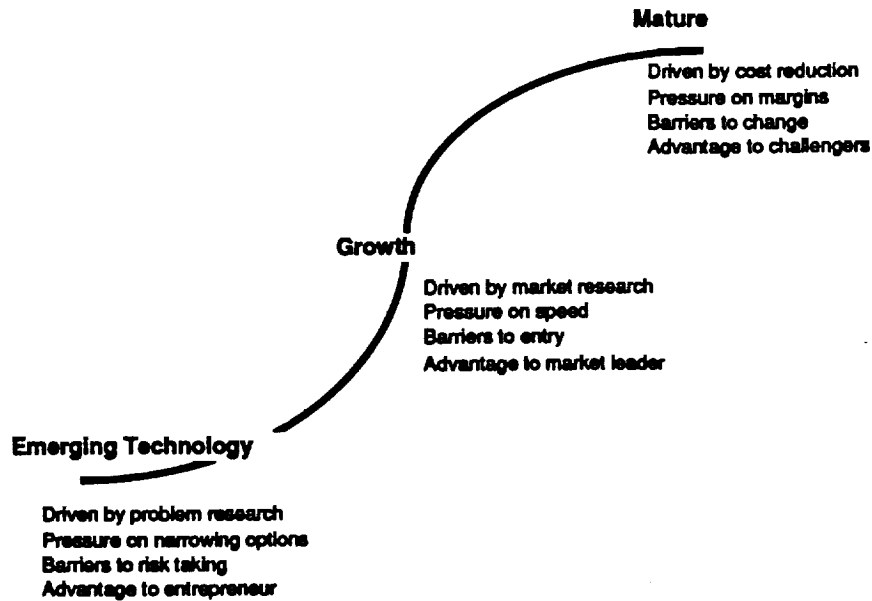
Mature

Driven by cost reduction
Pressure on margins
Barriers to change
Advantage to challengers

Growth

Driven by market research
Pressure on speed
Barriers to entry
Advantage to market leader

Emerging Technology

Driven by problem research
Pressure on narrowing options
Barriers to risk taking
Advantage to entrepreneur

Figure 2 Implications of Technology Maturity

Advanced Development	Implementation or Production
• Technical Management with assistant engineers	• Product manufacturing management with sustaining engineering core
• Work performed by specialists and technologists	• Work done by engineers and trained personnel
• Flexible operations and interaction	• Organized production
• Tight control possible	• Manufacturing tolerance necessary
• Small throughput and volume	• Large throughput and volume
• Low inertia	• High inertia
• Dedicated attention	• Large batch "philosophy"
• Judgement criteria	• Pass/Fail criteria
• Extensive rework practical	• Rework disruptive, uninterrupted flows, staging delays
• Flexible equipment	• Narrow latitude, several shift continuous operations systems
• Little documentation - data intensive	• Extensive documentation - data/operations intensive
• Cost not primary	• Cost primary
• Changes routine, easily implemented	• Changes difficult to implement
• Real-time analysis, traceability, and feedback	• Non-routine analysis difficult, feedback delay results in losses
• QA separable functions	• QA necessarily integral

Figure 3 "Both sides of the fence"[1]

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[1] "Technology: Development to Production:, J. L. Abita, IEEE Transactions on Engineering Management, Vol EM-32, No. 3, August 1985, pp 129-131.

We may establish an alternative view of Figure 3 by observing the relationships as depicted in Figure 4. This view enables a view of categories of issues as they relate to advanced development or production.

Issue	Technology or Advanced Development	Implementation or Production
• Management	• Technically oriented	• Product oriented
• Staffing	• Technologist and specialists	• Engineers and production personnel
• Throughput	• Small	• Large
• Inertia	• Low	• High
• Documentation	• Minimal	• Extensive
• Cost	• Not primary	• Primary

Figure 4 Simplified Look at Both Sides

The technology transfer process of tomorrow (Figure 5) must provide the environment to enable the identification of new requirements, emerging technologies with their forecasts, and insight into organizational capabilities. Thus, as technology items are developed, another process (outside the normal research process) is required to assure that these items have a reasonable chance of transfer to the end user. The environment established by the process must support and be sensitive to all the drivers in each organization, viz. their needs, their technology characteristics, their production capabilities.

2.1 Technology Readiness Levels

NASA's standard Technology Readiness Levels are depicted in Figure 6. For technology related issues, levels 1 through 7 are used. The additional two levels (8 and 9) are presented for completeness, i.e. to show the full development cycle. The levels are annotated to show the higher level relationships among the activities. In general, technology transfer occurs at the Technology Demonstration Level.

These definitions of readiness levels are just one way to characterize the complex technology development cycle. One must remember that this taxonomy is for general reference. The levels are to provide common ground or a context for the technologists and target users to establish mutual understandings. These levels should not be used slavishly, without thought, for then, they become an additional barrier to successful technology transfer. For example, consider the readiness levels are reflected in figure 7. This characterization is attempting to better describe a software-intensive technology development, whereas the standard readiness levels are more systems and hardware oriented. Although I took the liberty to annotate the software readiness levels with the same cycle description, there do remain numerous questions as to their mapping the same way as the standard readiness levels.

Differences in technology transfer can and do occur based on the level in the system hierarchy, viz from components to full subsystems.

Additionally, technology at one end of the continuum may have a very narrow (or even single) target user, whereas at the other end, the technology may have broad, generic applicability.

Programs have the option of tackling key technology earlier if the technology is mainstream to their mission. Thus, these levels are used as guidelines in preparing for the eventual insertion of new technology into mainstream use.
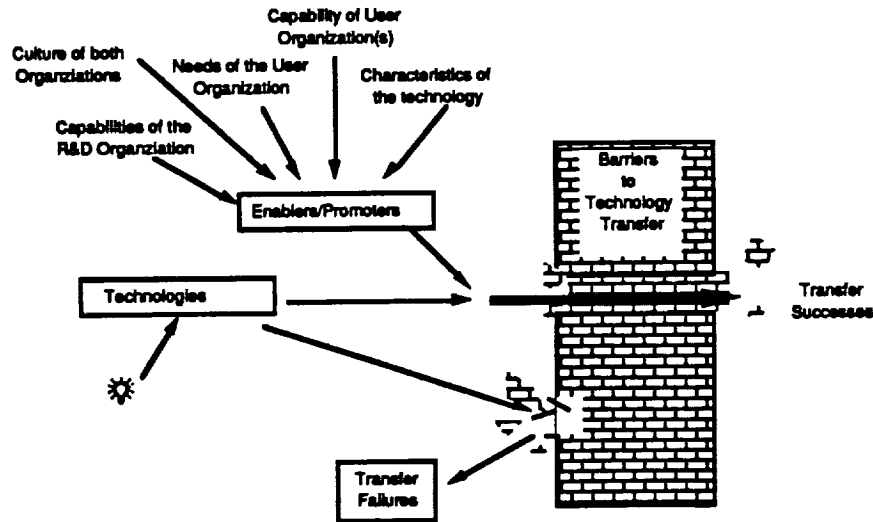
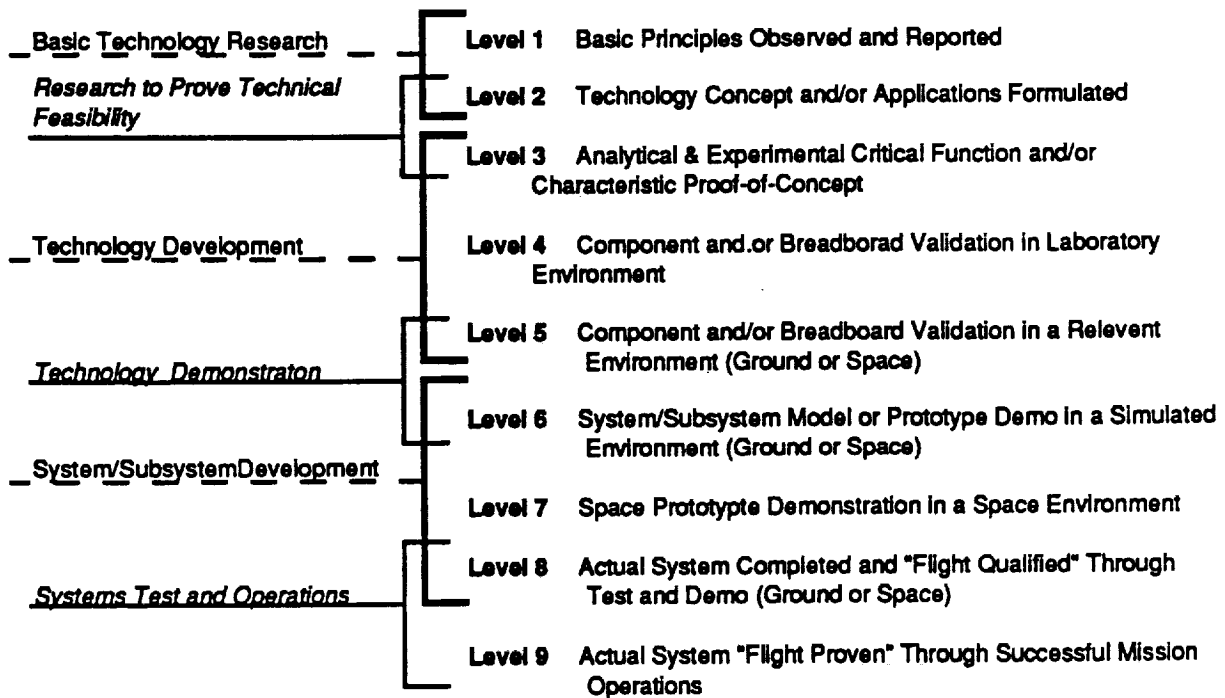Figure 5 Technology Transfer - Tomorrow[2]

Technology Readiness Levels

Basic Technology Research

Research to Prove Technical Feasibility

Technology Development

Technology Demonstraton

System/SubsystemDevelopment

Systems Test and Operations

Level 1 Basic Principles Observed and Reported

Level 2 Technology Concept and/or Applications Formulated

Level 3 Analytical & Experimental Critical Function and/or Characteristic Proof-of-Concept

Level 4 Component and.or Breadborad Validation in Laboratory Environment

Level 5 Component and/or Breadboard Validation in a Relevent Environment (Ground or Space)

Level 6 System/Subsystem Model or Prototype Demo in a Simulated Environment (Ground or Space)

Level 7 Space Prototoypte Demonstration in a Space Environment

Level 8 Actual System Completed and "Flight Qualified" Through Test and Demo (Ground or Space)

Level 9 Actual System "Flight Proven" Through Successful Mission Operations

Figure 6 Technology Readiness Levels[3]

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2 "Transferring New Technologies From R&D to Manufacturing," W. E. Souder and V. Padmanabhan, Research • Technology Management, September-October 1989, pp 38-43.

3 See the Appendix for a narrative description of these levels.
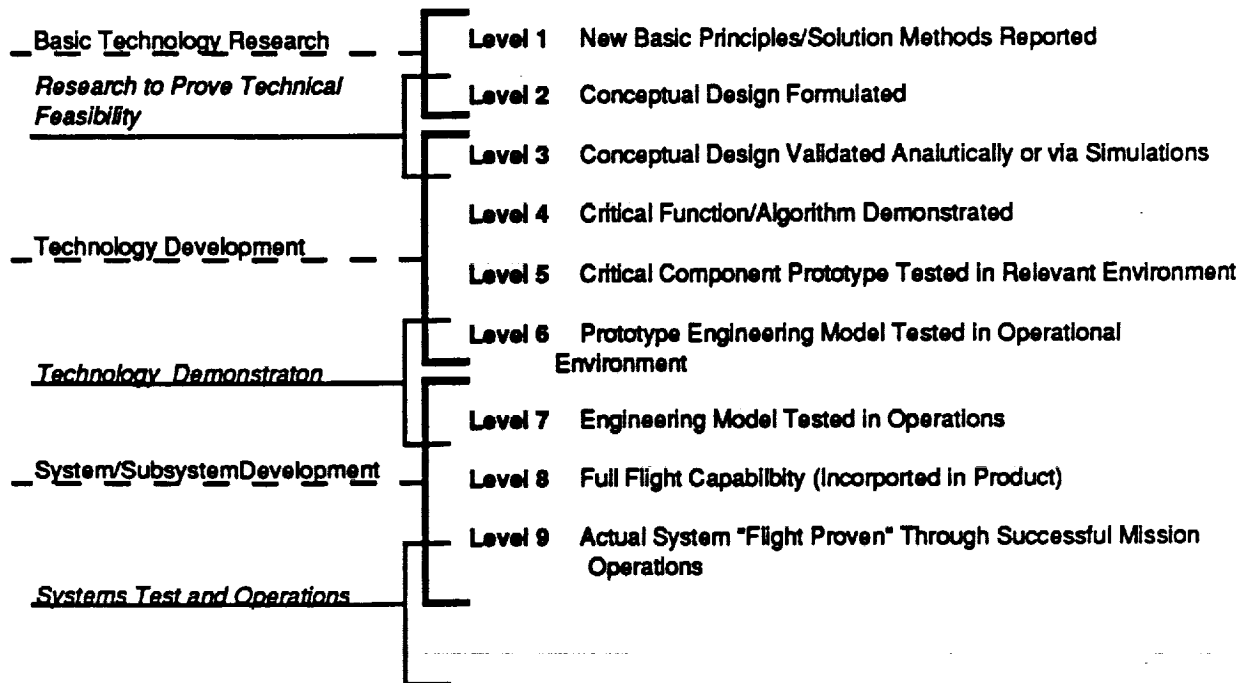
Software Technology Readiness Levels
(Proposed)

_Basic Technology Research _

Research to Prove Technical Feasibility

Technology Development

Technology Demonstraton

System/SubsystemDevelopment

Systems Test and Operations

Level 1	New Basic Principles/Solution Methods Reported
Level 2	Conceptual Design Formulated
Level 3	Conceptual Design Validated Analutically or via Simulations
Level 4	Critical Function/Algorithm Demonstrated
Level 5	Critical Component Prototype Tested in Relevant Environment
Level 6	Prototype Engineering Model Tested in Operational Environment
Level 7	Engineering Model Tested in Operations
Level 8	Full Flight Capabilbty (Incorported in Product)
Level 9	Actual System "Flight Proven" Through Successful Mission Operations

Figure 7 (Proposed) Software Technology Readiness Levels[4]

2.2 A Model for Technology Transfer[5]

A study at the Microelectronics and Computer Technology Corporation[6] focused on seven aspects of technology transfer: effectiveness of technology transfer at the consortium; effectiveness of various methods for technology transfer; importance of various factors in facilitating the technology transfer process; importance of barriers to technology transfer at both the consortium and the shareholder companies; agreement on who should set the research agenda; agreement on the type of research in which the consortium should be engaged; and agreement on ways that the consortium could improve the technology transfer process.

Based on this research four key variables emerged as especially critical in the technology transfer process: communication, motivation, distance, and technological "equivocality" (see Figure 8 Technology Transfer Matrix).

In Figure 8, each of the quadrants is discussed in the following:

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[4] "Technology readiness levels for Software", Robert C. Tausworthe, JPL IOM dated March 7, 1990.

[5] "Accelerating Technology Transfer in R&D Consortia", R. W. Smilor and D. V. Givson, Research • Technology Management, January-February 1991, pp 44-49.

[6] A major, for-profit, U.S R&D consortium that was established in 1983.

Communication - Both passive and active communications are involved in communications between technology developers and technology users. Passive communications have a broad sweep and are usually media-based. Here, greater care may be taken in packaging and producing a quality message.

Active links are direct, person-to-person interactions. They may range from teleconferences to *ad hoc* teams and onsite demonstrations. The benefits of active links center on the fact that they encourage interpersonal communications in terms of fast focused feedback, i.e. the researcher learns from the potential user and vice versa.

The fewer and more passive the links, the less likely the chance that technology will be successfully transferred. The higher or more active the communication links, the more likely the chance of technology transfer.

At JPL, communication is particularly important in that as large projects change their mission design or switch to an entirely different mission, the technology developers will be left with unnecessary or unneeded technology developments. This just leads to the need for clear, continuous communication. From this, it is also true that all this requires robustness to accommodate (or survive) change.
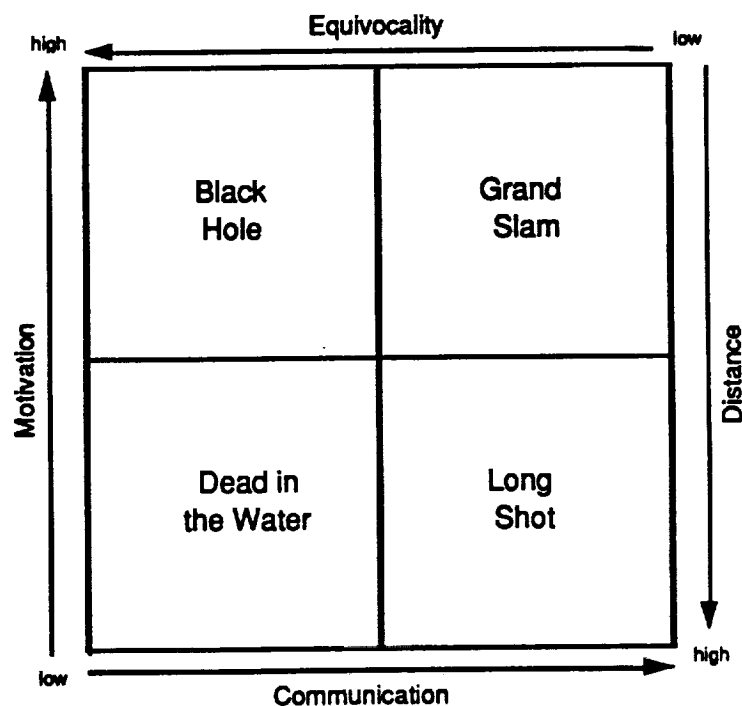
Figure 8 Technology Transfer Matrix

Distance - The second variable - distance - involves both geographical and cultural proximity or separation. Essentially, the result here is that the manager should endeavor to "co-locate" technology developers and their customers via promoting more active and direct communications links. (See Appendix A for additional information)

"Equivocality"[7] - This refers to the level of concreteness of the technology. Technology that is low in equivocality is fairly easy to understand, demonstrable and unambiguous. There is only one meaning to every individual involved in the technology transfer- the technology is understandable and its application clear. Of course, the higher the equivocality of the technology, the more difficult it is to educate the prospective users on the value or application of that technology. Clearly, this is part of the problem associated with communication.

Motivation - This involves incentives for and recognition of technology transfer. Motivation varies by importance of the technology transfer in the culture of an organization, the criteria by which the individual is evaluated, and the rewards established for those who engage in technology transfer activity.

Motivation means there is a definite answer to the question "What is in it for me?" when asked by the technology users and developers.

One can tell from the selection of the abscissa and ordinate axes labels that Motivation and Communication are the dominate factors in a successful technology transfer. As indicated above, perceptions of the maturity of the technology are directly related to the ability of the participants to communicate.

In the final analysis of this model, it would seem, at least from a JPL/NASA point of view, that one significant missing factor is cost or affordability. Fiscal considerations play a key role in both technology development and acceptance.

Technology transfer is "Dead in the Water" when there is low communication, low motivation, high distance, and high equivocality. The participants do not talk with each other because there are neither the incentives nor recognitions for those involved, because they are separated geographically, and because the technology is ambiguous and the application is uncertain!

What we want at JPL is the "Grand Slam." To achieve this we need high communication, high motivation, low distance, and low equivocality. In other words, because of highly interactive communication processes, because of a variety of incentives and recognition, and because the technology is unambiguous and its applications understood, successful technology transfer occurs. Of course, given JPL's relationship to NASA, all this must occur at NASA HQ also.

2.3   Barriers

Many of the barriers result from the fact that at any given time, no one is really focusing on what the next-step-after-this-version would be, that is to say: researchers are doing far-out exploratory work; a portion of development is producing the new systems required by the current missions; the balance of development is readying the next version for a continuing mission.

"Additionally, our factories and other workplaces have long been designed around management principles that prevent organizational flexibility and change. Harvard's Michael Porter describes it well: 'Change is an unnatural act, particularly in successful companies; powerful forces are at work to avoid and defeat it. Past approaches become institutionalized in standard operating procedures and management controls. Training emphasizes the one correct way to do anything; the construction of specialized, dedicated facilities solidifies past practice into

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7 Equivocality is defined to be - of doubtful advantage, or subject to interpretation.

expensive brick and mortar...' Such systems were simply not designed to react quickly, if at all, to rapidly changing conditions."[8]

Many would say that a fundamental problem in technology transfer is the lack of a way to bridge the technology transfer gap (Figure 9).
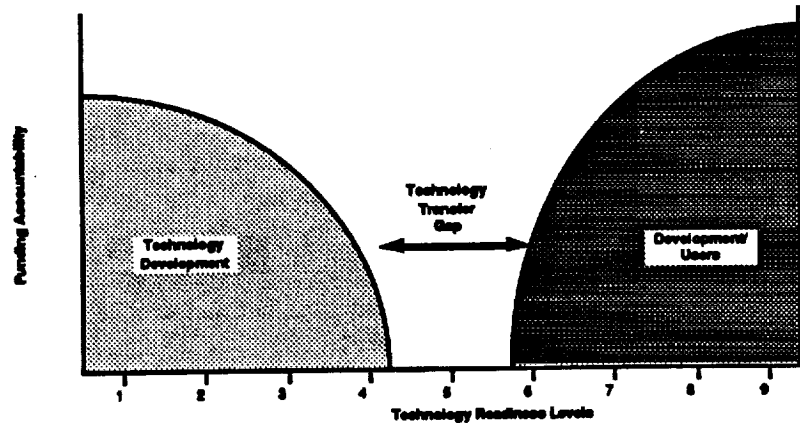

Figure 9 Technology Transfer Funding Gap

This gap is caused by two factors

(1) Historically, research is complete when a breadboard article has been validated. This validation, which occurs somewhere in readiness level 4, usually signals the termination of research funding (such as Code R).

(2) Unless the technology is fundamentally enabling to an endeavor, the flight project or consumer is usually hesitant to incorporate a new technology without the existence of an engineering model, at the very least. Additional confidence is built with the demonstration of the engineering model in an environment similar to the intended usage. Thus, users support (such as Code S) generally is not available until the technology reaches readiness level 6.

These two factors clearly indicate that each organization needs to recognize that co-accountability is the only way to affect the smooth insertion of this new technology in to mainstream usage. The Technology Transfer Plan is a vehicle to formalize this co-accountability and its eventual transfer to the using organization. In particular, the funding profile to bridge this gap is important (see Figure 10). The plan will document the transition funding profile required for successful handoff. Some of the issues facing technology transfer are beyond the scope of a single center. There needs to be a more complete technology transfer process that includes all the NASA centers and Codes S and R within NASA itself. Figure 11, NASA Technology Transfer Interfaces, depicts the needed interactions at various levels, i.e. starting with industry and academia through the Associate and Administrator level of NASA. Without explicit support within Code S for technology development/transfer activities, it will be difficult to insert new technology into on-going or new programs. This Code S funding

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8 "Technology Development in the 1990s: Will Government Polices Help or Hinder?", Speech by Robert M. White, Under Secretary for Technology, U.S. Department of Commerce, to Council on Superconductivity for American Competitiveness, September 14, 1990.

coupled with "good faith" support from the target user and Code R support, will provide the basis for successful technology transfers.
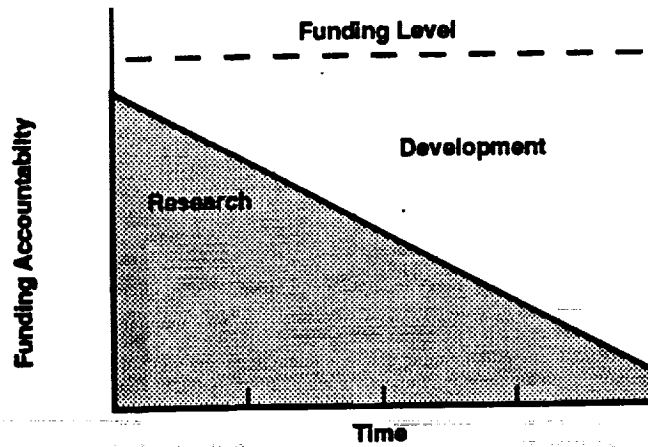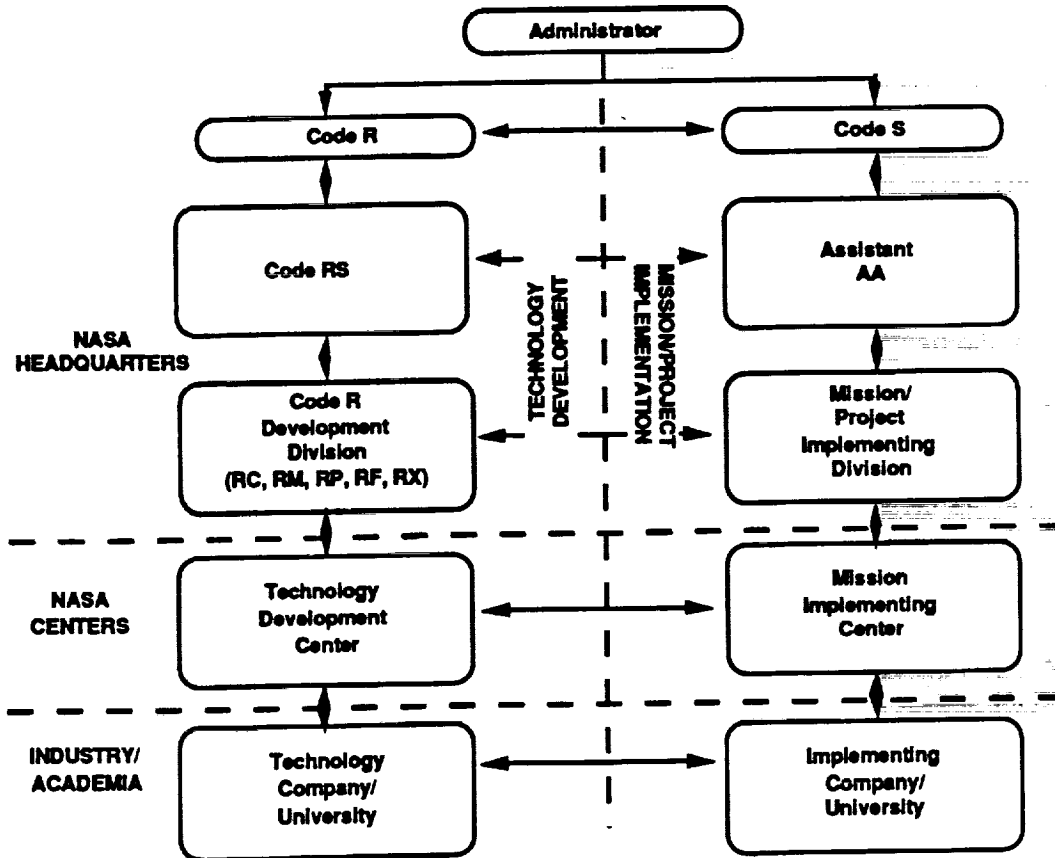

Figure 10 Funding Accountability

Figure 11 NASA Technology Transfer Interfaces[9]

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9 Adapted from drawings and ideas of W. J. Weber III at NASA/JPL.

Yearly exchanges between each column (as illustrated by the horizontal doubled-ended lines) would enhance the ability to identify needs (e.g. Code S) and emerging technologies (e.g. Code R). As part of this exchange, more cohesive programs of technology development and transfer could be established.

The significant barriers having differing effects are the variables of communication, motivation or advocacy, risk or maturity of the technology, and organizational structure (distance). Figure 12 lists some of the specific barriers identified at JPL and suggests dominate areas of effect.

Barrier	Comm	Advoc	Mgnt	Risk
The user community lacks a process to identify common technology requirements	X	X	X	
The user community lacks a vehicle to exert the collective leverage to cause JPL/NASA to implement common design.	X		X	
Resources invested in existing systems and applications, and the attitude and culture of the work force make it difficult to evolve to new technologies.			X	
Current practices encourage a tactical approach to solving technical problems while ignoring key strategic (i.e. long term) issues.			X	X
There are inadequate incentives fostering the insertion of new technology in to new missions. The linkage between technology payback and achieving missions goals is not strong.	X	X	X	
Fear of being unable to complete a mission (on-time, within budget, and meeting mission goals) using "newer" technology.			X	X
There is no documented, coherent JPL/NASA vision for broad-based technology integration and the role of technology transfer in achieving that vision.			X	
There is no shared vision for developing a technology transfer process.	X		X	
Transfer is further complicated by the fact that oft times capabilities rather than specific products must be transferred.			X	X
With today's projects, you cannot simultaneously accept a "fixed-priced" contract from Congress to develop a major undertaking and at the same time support technology development and the unavoidable attendant risks, i.e. cost uncertainty.			X	X
Inadequate staffing by engineering. A common response to the suggestion for new technology is "We do not have anyone here who has the technical skills and knowledge to incorporate this technology into current projects."			X	X
The perception that a technology is too complex will often lead the intended users to question the technology developers credibility.	X	X	X	
NASA does not develop serious plans beyond a five year new start horizon		X	X	

Figure 12 Barriers

2.4 Case Studies At JPL

Understanding the current state-of-practice for technology transition at JPL is important. It is important to understand the attributes of recent efforts at JPL regardless of their success or not. These interviews included both specific insertion efforts and knowledgeable peoples' general understanding and views on technology transfer. The specific efforts at JPL included:
- Viterbi decoder for Voyager and Galileo
- Solid state power components e.g. switches, microprocessors

- Fiber Optic Rotation Sensor (FORS)
- Onboard processing for CRAF/CASSINI
- Rhenium engine, electric propulsion
- Optical communications.

These were selected because they are recent and there exists an adequate body of current knowledge in order to extract some similarities, principles or guidelines.

Without identifying the specific task or individual here are some of their insights (these are broadly grouped via

Involvement:
- Cannot underestimate the value of the advocates/champions. This should be done even to the extent of transferring someone with the technology.
- With advanced technology funding support via Code S, FPO, OSSI, etc, the first-use-of-technology-eats-the-cost syndrome may be broken.
- User involvement is key to the successful transfer of the technology. This enables a "buy-in" by everyone.
- Technologist do not understand the paradigm for technology transfer. User confidence is everything. Technologist should consider all potential end-users as from Missouri, i.e. "Show Me!".

Focus
- Some efforts have not been successful because the technologist became enamored with technology as an end result in itself, thereby losing sight of the needs of the project. They focused on the wrong problem from a flight project point of view.
- JPL has made the mistake of putting the technical person in-charge, where a task manager is really needed. The technical support is required. One choice is to possibly placed the technologist on staff as the chief scientist, chief engineer, etc.
- When discussing technology transfer, we really need to understand the drivers. Is the project in dire need (technology pull)? Is the technology ripe and there are clear applications (technology push)? Is it basic, enable technology, thereby causing the user to take the technology earlier than normal (pre-engineering model development)?
- The flight projects have to very conservative because of risk. Users are generally unwilling to accept risk in the bus; there is after all only one bus and if it fails, the entire mission fails. Thus, the users are interested in new bus technology only if: (1) it is mission enabling, i.e. the mission can not be accomplished without this technology; and/or (2) it is reasonably mature, having reached the engineering model stage and thus represents no more than moderate risk.
- Flight project should not be involved in technology development.
- Technical risks in the instruments are often acceptable: a given mission generally involves a range of task performed by multiple instruments, so a failure of any one instrument does not result in failure of the mission as a whole.
- Even if a reasonably mature new technology and an interested user find one another, a final hurdle remains: the cost of full and final flight development of the technology must almost invariably be borne by the first user. The fact that such funding must be provided during the trying early years of a flight program makes this last hurdle much more difficult.

Options for making the process a smooth one:
- Technology does not come in spurts like spacecraft do. We need a continuous program (here you may read "real budget") to develop the underlying technology for later

insertion. (Comments like this lead to the question of "Why do not OSSI and FPO establish technology programs like TDAs?").

- A significant portion of the Advanced Technology Development funding from Code S goes into advanced mission planning; more should go in to technology planning and technology insertion support (bridging funding).

- With advanced technology funding support via Code S, FPO, OSSI, etc, the first-use-of-technology-eats-the-cost syndrome may be broken.

- When considering technology transfer, industry's role should be considered, particularly since we do not usually build production units. Can synergistic relationships be established with institutions such as Draper Labs?

- If a new technology is to be attractive and ready for use on a given mission, its development process must usually start well before the mission itself emerges from the pre-project phase. Unfortunately, this implies a chicken-and-egg problem: the prospective user in not interested in immature technology, but without user interest, it is very difficult to advance a technology to an attractive level of maturity.

2.5 Actions

There is a broad spectrum of actions that may be taken to address the barriers to technology transfer. These include:

Involvement:
- Assign top level champions (bilateral championship). They will be the advocates of the technology to the two organizations, i.e. the technology developers and users. They will draft and get concurrence on the Technology Transfer Plan.
- Involve the end user in the early stages of technology development. This involvement may range from publication distribution and review participation, to engineering involvement in design. This is necessary if the technologists want the potential users to ultimately accept the technology rather than disregard it as yet another example of "a solution looking for a problem."
- Encourage the users to participate in developing the technology. Too often technology developers have been content to "throw their product over the wall and hope someone will catch it (Figure 1)."
- Demonstrate the technology to the end user community. Provide opportunities for users to meet collectively and share their experiences, requirements and needs.

Focus
- Apply the technology to a few representative problems before attempting to transfer it[10]. Thus, the recommendation is to (1) whet the user's appetite by trying the technology on one of his applications by the technology developer in the laboratory, then showing him how successful it was, (2) invite the user to work on the second application, and (3) finally, initiate the transfer process, by letting the user choose the next application and start providing the development pull and fiscal support. It is here that one may want to consider temporarily transferring a technology developer to the project development team.

Options for making the process a smooth one:
- Provide training by the technology developers. Often the technology developers lose interest after the readiness stage; they do not want to write the user's manual or to

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10 Be willing to provide resources (people, time and money) to sell the technology.

think about features that may make it easier to use. Effective transfer requires these activities. Some accommodation must be formally made to effect this. Also, assisted by the technology developers, the consuming organizations need to provide formal training to the development engineers.

- Dedicate an engineer to monitor the transfer.
- Follow-up to determine the effectiveness of the transfer process. Never say "Good bye" -- feedback is important to the technology developers to fix immediate problems as well as considering improvements for the next round in the technology. The transfer process, itself, also needs calibration to enable improvement in the next round of technology transfer activities.
- Identify a host project. Given the "fixed-priced" mode of flight projects, what could help would be an arrangement whereby one or two targeted technology development activities would be taken on by a project with the up-front understanding that these areas would be excluded from the requirements of the "fixed-priced" constraints. Thus, a host project would be identified. This project would be the end-user for the technology in question.

The shotgun approach of overwhelming the barriers with actions/promoters can usually be replaced with a more efficient approach of eliminating barriers by matching them with specific actions. These actions will be codified via the Technology Transfer Process and its associated Technology Transfer Plans.

3.0 Technology Transfer

At this point, it is important to restate the definition of technology transfer:

> the transfer of organized knowledge to a project/program for the eventual purpose of producing new or improved, products, processes or services. Transfer will occur through one, or more, of the following modes: occasional consulting, documentation (reports, assessments, programs, or drawings), training (on-the-job, on-site or elsewhere) , demonstration (proof-of-principle or application to a real-world problem), and collaborative technical work.

Thus, again, given this definition and what has been dismissed previously, it is obvious that technology transfer is absolutely dependent on person-to-person communications and is affected by all those things which encourage or inhibit communications, such as need, funding or confidence. This communications must be between technology developers and the intended users, where users include not just the programmatic element, but the intended everyday utilizers of this technology. For without the ultimate end-users participation, the technology may be transferred, but not used (i.e. the transfer use not really consummated!).

We must overcome the general barriers associated with communications, motivation, technology readiness, and organization structure as described Sections 2.2. and the specific impediments as discussed in Section 2.3. Some of the significant factors concerning technology transfer from both the giving and the receiving perspectives include:

(1) Each transfer is really unique in the full sense of the word. The planning must address the ripeness of the technology (such as the needs of the receiving community or user; the complexity of the technology, that is to say is it a chip set or complete subsystem; and the maturity and skills of both organizations). Thus, application planning is one key to a successful technology transfer.

(2) <u>User involvement</u> is the next significant factor. Without the active sponsorship and support of the "host project", it is probably a case of "a solution looking for a problem."

(3) Since there are at least two organizations involved in the process, continuing, clear communication is essential. Open, working, active lines of communications are important to the continued ability to work out process and technical issues before they become too large to handle. Thus, <u>communications</u> is another key factor to a successful technology transfer.

(4) A <u>process</u> that encourages asking the right questions at the right time is next in our list of key factors. There are appropriate questions to be addressed at each stage (pre-transfer, planning, readiness review, and active transfer) of the transfer process. Often the process is complicated by not asking the appropriate questions.

(5) There is a real need to address the right questions at each step of the process. <u>Knowing the questions</u> and their logical location in the process is also key to the process.

(6) Often a transfer is attempted as a part-time activity or without clear lines of accountability. The results are slow or no decisions, lack of follow through which leads to frustration and ultimate failure. Clear lines of <u>responsibility and accountability</u> are the next keys to a successful technology transfer.

(7) Technology transfer becomes a <u>funded activity</u>. Funding is identified to bridge the gap between technology availability/demonstration and incorporation into a host project. With identified funding sources, technology comes of age in its own right.

As discussed above, technologies are "ready-for-transfer" at different stages in their development depending on the user's requirements, state-of-the art, etc. Thus, the process and documentation described in this section are only guidelines, and the reality is that each technology effort must be reviewed on its own merits. The appropriate level of technology readiness for transfer in any one case will depend on the needs and plans of the user organization to become involved in the development program and effect the technology transition into program and project activities.

3.1 The Process

The process should enable a "Grand Slam" (see Figure 8 and Section 2.2) and as such should provide for communications paths, motivation, and shortened communications distances.

Planning is the key to a successful technology transfer. Today, even if the technology developer and the intended user agree that the transfer is advantageous to each side, the lack of clear planning and understanding of the questions to be addressed, leads to, at the very least, a difficult time, and often to failure.

The Technology Transfer Process is depicted in Figure 13. This process addresses all the key factors described in the previous section:

- Planning

- User involvement

- Communications

- A process is required

- Knowing and asking the right questions

- Responsibility and accountability and

- Funding.

Each annual cycle starts with a review of inputs:

(1) the current program (on-going programs with their Technology Transfer Plan, and the current mission set),

(2) new requirements (input is based on future missions),

(3) new technologies (inputs consists of JPL thrusts, technology forecasts, and technology needs based on the future missions), and

(4) new out-year plan and schedule (inputs are all of the above).

The results of this review may be any of the following (based on the inputs)

- termination of an on-going program (destination the "86"-trash can).

- modification of an on-going program in the light of new missions, new requirements, and/or new technologies.

- standard continuation of current effort (probably with minor updates to the Technology Plan).

- initiation of a new technology transfer effort.

- end user acceptance of the technology!

A standard output each year is the forecast of upcoming technology transfer candidates on the 5 to 7 year horizon. This output provides a context and some continuity to the whole transfer as a set of activities.

The identification of a new candidate initiates a technology transfer cycle. After selection of accountable advocates (champions) two activities are started: writing the Technology Transfer Plan and preparation of a Technology Readiness Review. Besides the questions listed in Figures 14 and 15, the Technology Readiness Review will address issues such as:

- Basic concepts and technology associated with the transfer

- Mission requirements with derived requirements for this transfer

- State-of-practice contrasted with the state-of-art.

- Acceptance and success criteria for the receiver (host project).

- State of the technology development including proof-of-concept demonstrations, etc.

- Risk and affordability with respect to current technology and the needs of the intended users.

- Does the technology meet the needs of the intended receiver? What is paramount - performance? lifetime? reliability? mailability? ..other "-ilities"?

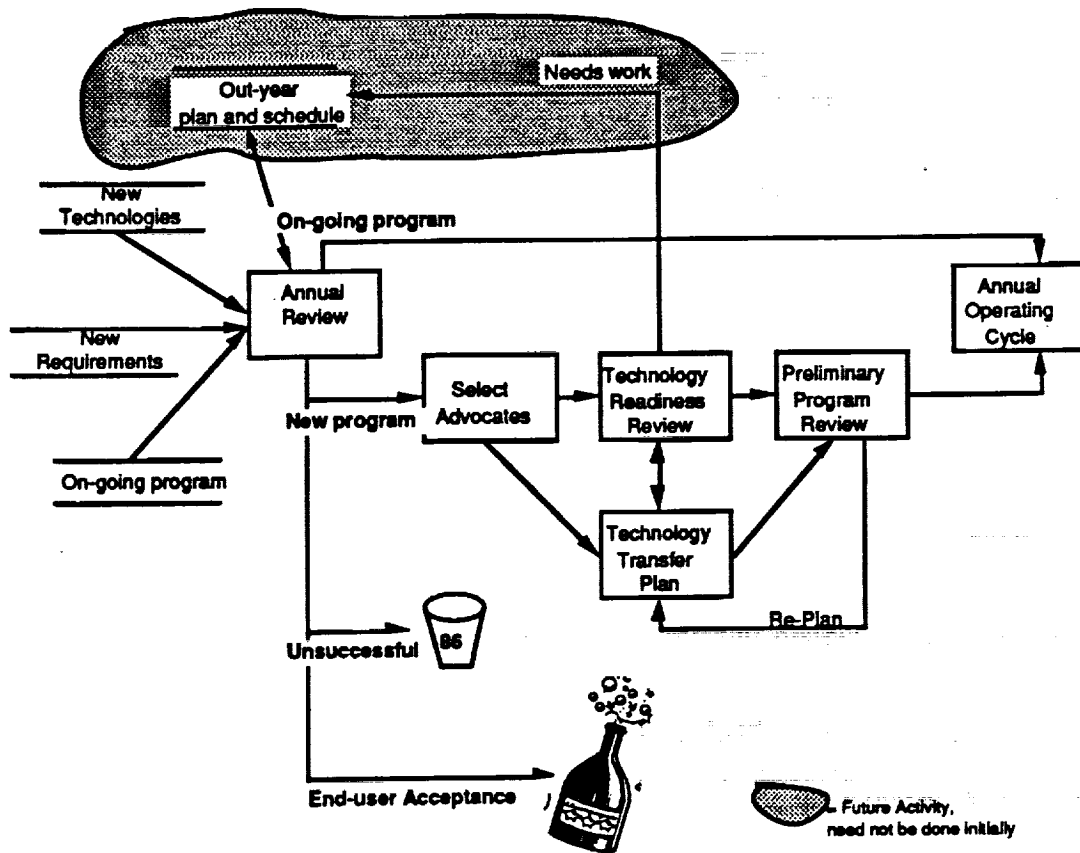- Summary of accomplishments, identified issues and potential risks.

Figure 13 Technology Transfer Process

The result of the Readiness Review should be permission to proceed. It is here that any special consideration should be documented, i.e. the need to proceed while keeping a backup position in a viable state. Readiness does not just refer to the technology but also the the intended user. That is to say that the needs of the ultimate user and the technology match or that they will actually use the technology!

- What impact can this technology offer our program/project?
- What are the costs/risks associated with introducing this technology?
- Where does this technology rank in importance to our program/project needs?
- Is there a plan to receive the technology in a timely fashion?
- Are there adequate resources to receive and develop the technology?
- What will be done to upgrade the staff, if that is necessary?
- Is there a champion/advocate for this technology? Is that person at the right level?
- Have we done an adequate job of sharing the program/project opportunities with the research organization?
- Does the giver have an understanding of the timing of our needs?
- Have we agreed on what constitute a demonstration of technical feasibility?
- What has been the history of the relationships between these two organizations? If there is a history, what are the strengths upon which to capitalize?

Figure 14 Checklist for the Receivers[11]

- What does the technology promise?
- How do the promises related to the program/project needs?
- What are the costs/risks associated with developing the technology?
- How is industry using this technology?
- Is the technology familiar/unfamiliar to the receiver?
- Where does this technology rank in importance to the receiver?
- Is there adequate technical expertise to pick up the research?
- If not, is there any training or recruiting support we can provide?
- Is management in the project/program committed to the technology?
- Have we adequately marketed the technology?
- Do the researchers have a comprehensive understanding of the program/project's needs and opportunities?
- Are there adequate resources to research? To transfer the technology?
- What documentation does the receiver need? Has it be produced?
- Is there a plan to deliver the technology is a timely fashion?
- What is the proper hand-off of this technology?
- Have responsibilities been mutually delineated and accepted?
- Has the information exchange been thorough and timely?

Figure 15 Checklist for the Givers[12]

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[11] "A Study of the Factors Which Affect Technology Transfer in a Multilocation Multibusiness Unit Corporation", M. L. Ounjian and E. B. Carne, IEEE Transactions on Engineering Management, Vol EM-34, No. 3, August 1987, pp. 194-201.

[12] Ibid.

3.2 The Plan

With the goals defined, the technology transfer advocates derive a detailed plan from a general ordered outline. This Technology Transfer Plan (see Figure 16 for the outline) is a management artifact. Its purpose is to establish ownership of the transfer of technology between peer organizations, i.e. a peer-to-peer process. This plan will also serve as a driver, check list, and guide, especially since each task description explicitly relates schedule and responsible person. In essence, this plan documents the effort, discipline, rigor, and order that are necessary to make it all come together.

The authors of the plan are the two advocates. Approval includes: advocates, program office(s), developing.organization(s).

4.0 Summary

The problems associated with technology transfer are complex. Some of the Do's for a successful collaboration and hence a successful technology transfer include:[13]

- Treat the technology transfer as a personal commitment. It is people that make partnerships work.

- Anticipate that it will take up management time. If you can not spend the time, do not start the transfer.

- Mutual respect and trust are essential. If you do not trust the people you are working with, forget it.

- Remember that both partners must get something out of it. Mutual benefit is vital. This will probably mean that you have got to give something up. Recognize this at the outset.

- Do not put off resolving unpleasant or contentious issues until "later".

- Recognize that during the course of the transfer/collaboration, circumstances and markets change. Recognize your partner's problems and be flexible.

- Make sure that you and your partner have mutual expectations of the transfer and its time scale.

- Get to know your opposite numbers at all levels.

- Appreciate the cultural differences. Do not expect a partner to act or respond identically to you.

- Recognize your partner's interests and independence.

Each technology transfer is unique, and as such, requires careful planning. At the least, this planning must detail (1) the technology to be transferred, (2) the readiness of this technology,

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13 "The Global Logic of Strategic Alliances", K. Ohmae, Harvard Business Review, vol 67, No. 2 (March/April), pp. 143-154.

(3) the needs of the intended users, (4) the process and schedule for the transfer, and (5) the acceptance criteria of the user (i.e. how do we know when the process has been successful?).

The basic dimensions of motivation - the organizations and individual, communications between the technology developers and intended users, organizational complexities, and maturity of technology, itself, provide a rich base of solutions. These dimensions lead to essential factors requiring attention are planning, user involvement, communications, a process, knowing and asking the appropriate questions, assigning responsibility and accountability and finally, recognition that little is accomplished without adequate funding.

The detailed solutions just compliment the key factors (listed above). These factors are embodied in the steps of the process that is described in Section 3.1.

Section #	Title	Description
1.0	Introduction	
1.1	Identification	Project name
1.2	Overview	Brief description of the Project. Brief statement of what this Technology does.
1.3	Document Scope	What this document addresses and how it relates to other documents
1.4	Controlling Documents	Documents that control this document
1.5	Applicable Documents	Documents referenced by this document
2.0	Organization and Responsibilities	The TTP shall provide definition of roles and responsibilities of personnel and their relationships. Show the project organization chart. Show an activity or product-oriented work breakdown structures with a mapping to the organization chart.
3.0	Polices and Constraints	
3.1	Project Polices	Polices to be applied to this work
3.2	Project Standards	Identify JPL and other standards that are to be used. Describe the milestone reviews. Specify the convening authority for each review.
4.0	Technical Approach	
4.1	Work Inputs	Describe all inputs from other organizational elements. Identify source, need date, acceptance criteria.
4.2	Technical Constraints	
4.3	Deliverables	Definition and scope of the work to be accomplished. Identify products to be delivered.
5.0	Methods, tools, and training	Identify the management methods to be applied for resource monitoring and control, configuration management, and product assurance. Include regularly scheduled development status reviews.
6.0	Metrics Reporting	Specify data to be reported to monitor work accomplished, resources consumed, products generated, and problems encountered for each phase of development.
Appendix A	Glossary	
Appendix B	Acronyms	
Appendix C	Budget	
Appendix D	Schedules	

Figure 16 Transfer Plan Outline

Appendices

Probability of Communication in Organizations

In Managing the Flow of Technology there were three charts depicting the Probabilities of communication between people under differing circumstances. These are reproduced here.

Figure 8.2 The Probability That Two People Will Communicate as a Function of the Distance Separating Them (100 Meters to 255 Kilometers)
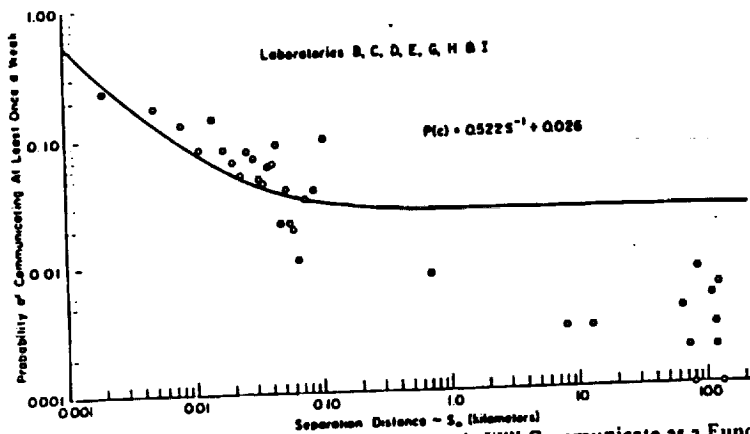

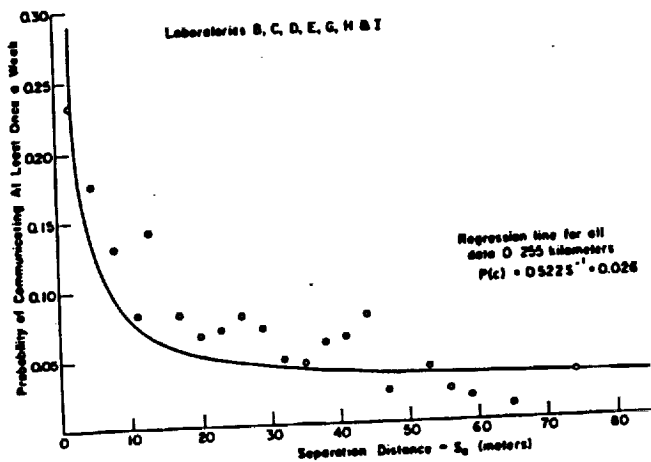Figure 8.3 The Probability That Two People Will Communicate as a Function of the Distance Separating Them (0–100 meters)
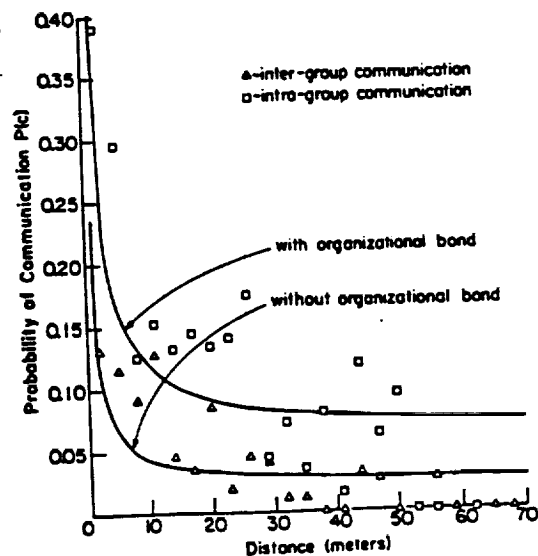

Figure 8.4 Probability of Communication as a Function of Distance—Controlling for Organizational Structure

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Technology Readiness Levels Descriptions

Level 1 Basic Principles Observed and Reported - Preliminary efforts are expended to identify the new technology and its applicability, and to provide a mathematical, empirical, or other supportive, basis to believe in the successful creation of the technology.

Level 2 Technology Concept and/or Application Formulated - Based upon preliminary work, the concept for the technology is evolved to specification of components, limits, and capabilities.

Level 3 Analytical and Experimental Critical Function and/or Characteristic Proof-of-Concept - The elements which make up the technology are constructed. In a piecewise fashion, each required function is created and tested.

Level 4 Component and/or Breadboard Validation in Laboratory Environment - Each element is integrated into a demonstration of the technology y. While limited in scope, application or performance, the breadboard serves to prove the feasibility of pursuing the development. The breadboard also helps to identify limitations, errors in components and, perhaps, flaws in the basic theory or empirical studies.

Level 5 Component and/or Breadboard Validation in a Relevant Environment (Ground or Space) - Following successful breadboarding, a prototype for the the technology is constructed and tested in the working environment. This level serves to affirm that the basic theories and motivations for the technology are correct.

Level 6 System/Subsystem Model or Prototype Demo in a Simulated Environment (Ground or Space) - Sometimes the prototype is transitioned into a ground qualified application of the technology. Tested in an operational environment, the proof-of-concept model is used to assure that no major technological flaws exist which might limit or jeopardize the operational use of the technology.

Level 7 System Prototype Demonstration in a Space Environment - When appropriate, the ground qualified unit is test during spaceflight. This is the ultimate check that the technology and its embodiment are correct for the intended function in the spacecraft application.

Level 8 Actual System Completed and "Flight Qualified" Through Test and Demon (Ground or Space) - Given correct operation during qualification, the embodiment of the technology is placed into operational status. Operational status primarily assures future users that there is little or nor manageable risk in applying the new technology and that the cost of implementation and operation/maintenance is reasonably understood.

Level 9 Actual System "Flight Proven" Through Successful Mission Operations - Common usage.