THE IDENTIFICATION OF CAPABILITY

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Introduction

This report proposes to provide a specific measure of capability based against realizeable criteria. In the past, the work "capability" has been freely bandied with no definition of individual meaning and no way of determining other than lip service or "gut feeling." It becomes necessary, then, to provide a definition(s) for mutual understanding and agreement and criteria for measureable results.

The report is based in two studies conducted by Human Engineering Branch under Marketing Support. The first of these was proposed to provide a method for a general measure of capability and the second was undertaken as a portion of the present study to provide specific measures in the study area. A brief resume of both studies is reported here.

SECTION I
DEFINITIONS AND CRITERIA FOR CAPABILITY

Definition of Capability

In order to discuss capability, it is first necessary to agree on a definition or definitions of capability. Three definitions have been tentatively selected on the basis that they cover an inclusive range of expressions of capability and that the definitions are oriented towards industrial usage.

The first definition is the "ability to repeat previous work efficiently." This is proficiency - the ability to manufacture, process, etc. The second definition is the "capacity to extend previous knowledge on findings beyond original bounds to a new configuration." This is design capacity - the ability to develop. The third definition is the "talent to conceptualize or discover new ideas, approaches, products, theories, etc. This is creativity - the ability to reach new frontiers.

Each of these definitions implies a different set of criteria against which to measure the degree of capability that a chosen unit represents within each definition respectively. A rough group of criteria have been set down for each definition. These criteria are not fixed as yet but present a point of departure from which the final criteria will be established and fixed. The first definition - proficiency seems to involve these criteria:

1. Number of bodies
2. Number of skills and bodies in each skill category.
3. Organization resources, facilities, etc.
4. Pertinent previous experience
5. Morale

The second definition, design capability seems to involve these criteria:

1. Education of bodies (degrees, etc.)
2. Engineering skill
3. Expertness
4. Working climate
5. Previous design versatility

The third definition, creativity seems to involve these criteria:

1. Background of bodies
2. Previous conceptual work
3. Publications
4. Patents
5. Problem solving ability
6. Ability to direct research
7. Research interest
8. Willingness to accept failure

While criteria in the first group seem to exhibit their own yardsticks (i.e. it is simple to count the number of bodies in each skill group) as criteria become more ethereal, it is more difficult to state the measures which should be used to indicate satisfaction of the criteria. The measure of proficiency has been to a great extent, dealt with previously. Many measures are available here such as unit or dollar output per man or organization. These measures are generally available and, at present, it is not the intent of this report to offer any further work in this area. It is deemed more important to consider measures in those areas which are more difficult to define.

In the course of this study an attempt was made to determine definitions or capability other than those suggested by the author. A small experiment was run in which 12 subjects were asked to independently rank order the same 12 subjects, including themselves, on the basis of "capability." No definition was given of what was meant by capability, the decision being left to the individual. There was excellent rater agreement as to the hierarchy of capability within the group. After the subjects had completed the rank ordering, they were asked to state the reasons why they chose the top two as being more capable than the bottom two names on their respective lists. The group was then divided into three groups on the basis of where individuals were rated as to capability. The groups consisted of the top three, center six, and bottom three subjects. The reasons for ranking choice were examined for each of the groups. The top group chose as its criteria for capability items such as:

(a) Greater responsibility for original work
(b) Greater responsibility for work of others
(c) Complexity of assignments accomplished
(d) Variety of assignments accomplished
(e) Sound judgment

The middle group chose as its criteria for capability items such as:

(a) Experience
(b) Education
(c) Background
(d) Aggressiveness
(e) Leadership
(f) Knowledge
(g) Intelligence
(h) Aptitude

The lower group chose as its criteria for capability items such as:

(a) Accuracy
(b) Constancy of effort
(c) Productivity
(d) Self-assurance
(e) Responsibilities
(f) Knowledge

From an analysis of the various group responses it would seem that the top group defines capability in terms of the creative and directive capability, the middle group defines capability in terms of background or development capability and that the lowest group defines capability in terms of productive capability or proficiency. There is reason to suspect that workers, engineers and scientists will offer some clue as to their own capability by the terms in which they define capability.

Some Possible Measures For Capability

Shockley* indicates that there is a very high correlation between quantity of scientific production and the achievement of eminence as a contributor in the scientific field. Information garnered for this article tends to show that for a cross section of scientific personnel there is a correlation between their eminence and the log-normal distribution of their publication rate. It is further interesting to note that a curve of patents granted follows the curve of publications generally, however, the patent curve exhibits a greater slope. The article generally indicates that the top 5% brings out about 40 times the number of publications of the lowest 10%. The standard of publication is based on reporting in science abstracts. There would seem to be a logical approach to the identification of scientific talent here.

Figure 1, "Criteria Used by Outside Sources," provides the basic data for Shockley, above, as well as for similar studies conducted by Dennis and the Arthur D. Little Organization. It is interesting to note that the Little study indicates a correlation between the rate of publication and the receipt of research grants. This may be indicative of the hoped for success of submitted proposals. This was followed up in the study and the results are discussed later.

Shockley reports that election to American Men in Science was an indication of criterion peer recognition. Accordingly, the 1955 edition of American Men of Sciences, Physical Sciences, was searched to determine Northrop's standing in comparison with other aircraft manufacturers. The results are shown below:

Scientists in A/C Elected to American Men of Sciences**

1.	North American	40	10.	Bell	6
2.	Hughes	34	11.	NORTHROP	5
3.	Bendix	29	12.	Grumman	5
4.	Boeing	17	13.	Fairchild	4
5.	Lockheed	16	14.	Marquardt	2
6.	United Aircraft	14	15.	McDonnell	2
7.	Douglas	13	16.	Republic	2
8.	Convair	9	17.	Martin	0
9.	Aero-Jet General	9			

* Shockley, Wm., "On the Statistics of Individual Variations of Productivity in Research Laboratories," Proceedings of the IRE, Vol. 45, pp 279-290 March 1957.

** A follow up of the Northrop listings indicated that only one name was still employed at the study time. It is still possible that the latest edition of American Men in Science could change this considerably.

Hypotheses For Further Study

Based on these studies, it was hypothesized that publication and patent rate correlate with capability. A second hypothesis was advanced that the receipt of research grants was a manifestation of user acceptance and would be indicated here by proposal acceptance. Third, it was hypothesized that research and/or analytical organizations would be more likely to publish and that development and/or test organizations would be more likely to patent. To determine which organizations fell into which categories the functional summaries for each engineering organization within Norair were examined. Keywords or phrases were chosen to indicate the organizational responsiblities. These are indicated in Figure 2. Additionally, as indicated in Figure 2, these categories agree with the classifications for Engineering hire.

Organizations* were classified according to this scheme and personnel resumes were searched for indications of publication and patents. Resumes were taken as they existed, admittedly rough, with no attempt to determine the publication media or rates or patent dates. Although no analysis of statistical significance was done, the results in general (Figure 3) substantiate the hypothesis that research and analytical organizations will publish and development and test organizations will patent. One notable exception occurred (H) and this was found to be due to one individual's work. The organization was actually a support organization.

Preliminary Study Results

On the basis of the rough pilot study it was concluded that:

1. There is a negative correlations between patents and publications, that is if an individual was publishing he was unlikely to patent.
2. There is no significant difference in patent or publication rate between holders of BS or MS degree.
3. PhD's have a significantly greater publication rate.
4. There is no significant difference in patent or publication rate between professional or non-professional engineer.
5. There is no significant difference in field of training or specialization.
6. Chiefs are significantly greater in patent activity.
7. Specialists are significantly greater in patent activity but considerably lower than chiefs.

* Organizations is used here as a generic term. The organization may be a branch, department or section. The inconsistent form of available data forced this approach.

It must be understood that the above conclusions are based on resumes as they were written which necessitated some assumptions as to what "several" articles meant, and that if certain accomplishments were not shown they did not exist. This was refined in the second phase of the study and is discussed there.

Differences in Engineering and Scientific Personnel

An attempt was made to define the differences that lie between the scientist and engineer in terms of three areas; background factors, personality factors, and goal orientation. These differences are shown in table below:

Some Factors of Engineering & Scientific Image

Engineering Image	Scientific Image
Background Factors	
67% have one or more degrees	94% have one or more degrees
66% 40 years or younger	78% 40 years or younger
15% between 20 and 30	35% between 20 and 30
59% less than 10 years experience	66% less than 10 years experience
Personality Factors	
Needs definite structure	Tolerant of ambiguity
Must have order and integration	Prefers complexity
Must be right	Takes calculated risks
Cannot stand failure or criticism	Accepts failure
Works by time scheduled activity	Subject to personal work rhythms
Goal Orientation	
60% Top and middle management	62% Professional
18% Engineering heads	38% Administrative
11% Engineers	
6.7% Contribute to field	
3% University	

These factors, based on studies (1400 Engineers responding, 300 scientists responding) would indicate that the engineer generally has less education, is older, and has more experience than the scientist. He also does not work well without structured direction and is more cautious in his decisions. The disregard for failure may cause the scientist to make more mistakes but he is also more likely to make a creative contribution. Where the engineer is likely to be politically more aware, since he sees his future in management, the scientist is likely to have less consideration of administrative problems by his interest in professional achievement.

Capability as an identificable entity cannot be considered in a vacuum. Though the individual is necessary, by himself he is not sufficient. He must have available two classes of support element; work facilities and his image environment. Work facilities are considered in the chart below in terms of some cost requirement for R & D.

Cost Requirements of R & D*

Size of Labs by Number of Scientists and Engineers	Average Annual Cost	Cost Input Before Significant R & D Results
10	350,000	1,050,000 - 1,750,000
20	700,000	2,100,000 - 3,500,000
30	1,050,000	3,150,000 - 5,250,000
40	1,400,000	4,200,000 - 7,000,000
50	1,750,000	5,250,000 - 8,750,000

* Based on figures for aircraft industry as given by C. Wilson Rundle, "Problems of R & D Management", Harvard Business Review, Jan.- Feb. 1959 Volume 35 #1, p 28.

A cursory analysis of these figures indicates that the average research personnel will need about $35,000 a year for support, and will take 3 to 5 years before producing significant results. Further support is needed, however, not in terms of facility dollars but in terms of environmental and goal factors for job satisfaction. The payoff time, as indicated above is long as to make it necessary to provide incentive to stay. Some of these incentives are listed below:

- Professional atmosphere
- Work and thought privacy
- Access to professional expansion
- Time to publish significant findings (assuming no proprietary information)
- Reasonable freedom of expression and movement
- Reasonable expectation of recognition in the form of pay or advancement.

SECTION II

CORRELATION OF MEASURES

Professional Propensity

The second phase of the study was devoted to trying to determine whether any relationship could be established between the propensity to publish and/or patent and some concrete indications of acceptance of the groups who do.

A questionnaire was distributed to all engineering classifications in order to identify specific publication media, patent activity, calendar time of accomplishement, and employee hire date.

These data were analyzed first to determine whether Norair influenced the individual propensity to publish or patent. It was hypothesized that more publications and/or patents would be normally expected post-Norair hire than pre-hire due to increased age and experience. It was recognized that the length of time at Norair as opposed to pre-Norair would influence the rate but it was assumed that over a total group this would be likely to balance out. Figure 4 presents the publication and patent activity in terms of numbers, contributors, pre and post Norair hire. The propensity is presented as a ration of post-to pre-hire. Patent rate is significantly higher (1.68), this is in line with expected trend although the degree seems high. Publication rate (0.768) is significantly lower than would be expected.

From these results it can only be concluded that Norair tends to encourage the propensity to patent and inhibit the propensity to publish. This is understandable and probably very logical in that Norair functions as an Engineering Organization. Considering that this study is based on early 1960 data, it is conceivable that the division orientation has been changing, and that present information, if analyzed, might provide somewhat different results.

Sales and Publication Comparison

Validation of the usefulness of the projected measures was sought in terms of the possible correlation between amount of publication and company sales. A random sample of professional meetings for a one year period was determined. Assuming that papers selected were either invited or chosen by a peer group it would appear logical that the delivery of a paper would constitute peer acceptance. Thirteen aircraft manufacturers were chosen as the competive field and the number of papers delivered by each was plotted against the sales for respective manufacturers (Figure 5). Unfortunately, the sales figures available were for the year, 1958 as opposed to papers given in 1959. The trend between the two bears reasonable relationship. However, it must be recognized that the increased participation could possibly result from (1) the difference in numbers of personnel, (2) difference in manufacturers encouragement and support (3) factors of geography (i.e. submission of papers may be limited to local meetings in company philosophy). These results are shown in Figure 5.

Figure of Merit

It was felt that a scale of measurement of capability in terms of publications could be provided. However, where a positive independent measure seemed impractical, a relative measure of inter-company standing within Norair Engineering could be provided. Assuming that work and educational background is correlated with job level it seemed logical that output in terms of patents and publications should correlate with job level. Therefore, the responses were divided by job levels of the respondents; Chiefs, Supervisors, Engineering Specialists, Senior Engineers, Engineers, Associate Engineers. Categories were established for patents and/or publications in terms of number of publications, number of technical publications, number of trade publications and number of patents. The total number in each category was established for each job level, and divided to determine an average man/category/job level expectation. The product of the number of personnel in each job level and the expected category output were summed for each organization to provide an expected category output per organization. The actual category output per organization was divided by the expected category output per organization to yield a figure of merit. Figure 6 indicates these results for technical publications and patents for research and analytical organizations while Figure 7 provides the same for Design and Test Organizations.

Correlation of Figure of Merit and Proposal Success.

Effectively, from a management standpoint, the real criteria of a useful measure is the ability to predict success either in expense reduced or business gained. To this end an attempt was made to correlate the measures demonstrated; the ability to garner business, i.e., proposal success. Figure 8 indicates the results in terms of Figure of Merit vs ratio of proposals (in dollars) bid and won and ratio of cost of accepted proposals by organizations. Although the three curves are shown separately they can be superimposed on each other. The limited proposal success information available, since major proposals could not be attributed to a single organization for comparison allowing only small proposals to be considered, provides nothing more than a trend indication. This trend, however, is positive and would suggest that there is a positive correlation between the Figure of Merit and the likelihood of proposal success. It must also be remembered that the consideration is limited to those organizations which submitted proposals in the time period.

SECTION III

IDENTIFICATION OF CAPABILITY IN G. S. S.

While capability can be relatively identified in terms of three general definitions (creativity, design capacity, and manufacturing proficiency), the identification of a specific capability to accomplish specific work demands an additional set of criteria. To make this determination it is necessary to establish some basic assumptions and their necessary conclusions.

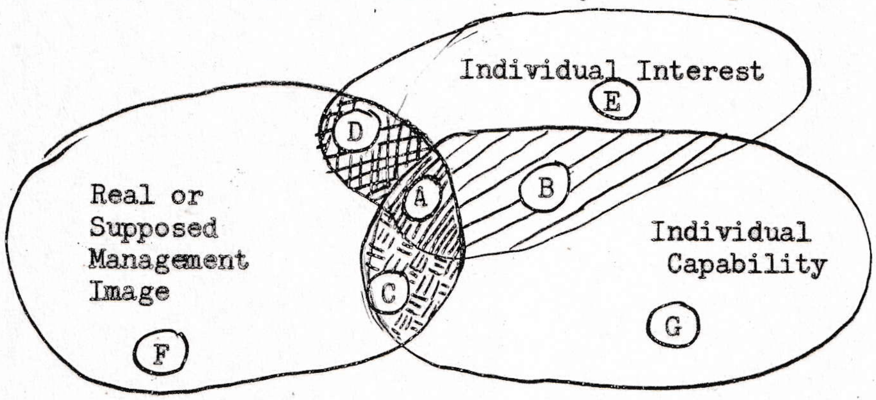
1. Capability is not in the walls but is a function of the individual or individuals.

2. The human will tend to try to work within the confines of his capabilities and interests.

3. The management image tends to limit these areas of capability and interest.

4. The highly capable will tend to try expanding his work areas of interest beyond the management image. This is to some extent a qualitative measure of capability.

All of the above can be illustrated by the diagram below.



a. The individual may assume that the area F, C, A, D, "Real or supposed management image is culturally, politically or ethically higher and thus sublimate his" individual interest area (E, B, A, D) to include only those areas which fall within the management interest (A & D) or even to change his interests to encompass more of area (F).

b. The individual may determine where his interests and capabilities coincide (A B) but choose to work in area (A) since he conceives this (politically) to be his function in the organization.

c. He may choose to work within his capabilities solely, regardless of interest and stay within the management image as he conceives it, i.e. areas (A C).

d. He may choose to work within his capability and interest, areas (A B), regardless of the management interest. We must assume that this will be the course of the man who has a strong capability in a specific area since he will not be worried about his ability to retain or get a job, his predilection for this area will be intense and he has made a choice as to a course of action in order to achieve any recognition for his capability.

One way of making these determinations is through proposed research projects, i. e. those projects which the individual would work on if he had the freedom and support. Further, the amount of these projects submitted in specific areas is some indication of the amount or original or creative thinking. This may be enhanced or degraded by management attitudes, specific or general, at any managemement level or by the way in which the individual sees management thinking.

An examination of theproposed research projects in the fiscal 62 budget provides this information. Based on the assumption that the study objectives as expressed present a reflection of the individual capability and interest and that the amounts appropriated are a management assessment of their own image and the relative worth and need for the study, less than 1% of the budget ($15,000 out of $1,560,000) is earmarked in the G.S.S. area. On the basis of this examination it can only be concluded.

1. That no, or an extremely limited capability exists, or

2. That the capability that does exist has been held down either by:

   a. Direct action of some level or management, or

   b. A real or supposed management interest, as the individual sees it.

In either case no evidence of a capability in this area is apparent or can be identified superficially.

It is necessary to provide the ways of making the determination between (1) and (2) above and the manner in which management can go about building a specific capability if desired.

It is first assumed that management, based on the present study, has made a decision as to what areas it might want to explore. It is assumed that the best recognition of capability will come, as described previously, from peer groups. It seems patently obvious then that an attempt must be made to determine a peer group which could point out the population of desirable selectees. Strangely enough, this could be ideally initiated through the combined intelligence which Marketing has. For example, those marketing types who have been concerned with G.S.S. could select key people in various user agencies and ask them for a rank order preference list of specific people they would choose if they were to try to organize an ideal G.S.S. group. From these lists, concensus opinion should provide key men who might form the basis for a specific capability. It is also conceivable that these lists may include personnel within Norair. If so, this would unearth an already existent capability.

What is assumed above is that capability stems from technical leadership. There is a good deal of evidence that strong technical leadership attracts and tends to develop technical capability. Further, since the user has identified the key personnel, there is already user acceptance and agreement on the existence of a capability, once these personnel are hired.

Ther is however, a necessary note as to what constitutes strong technical leadership. The influence of a single man as a technical leader is felt not only through his own individual contribution, but through the fact that his ability and eminence attract associates who can and do contribute. Additionally, his spark can bring out the best of the effort which will surround him and his guidance will channel this productively. To quote Arthur B. Little*

> ".....the surest path to progress in basic research is to secure the services of the most competent scientists within the field. Heavy reliance must be placed on their judgement. Often they are the only ones possessing the vision or curiosity to suggest initiation of research projects necessary to the creation of certain new and useful facts. ----the rate at which the competent man can contribute to science multiplies rapidly through his guidance and influence on his associates."

* Arthur B. Little "Basic Research in the Navy" Navy Research Contract NONR 251600, Volume 1, June 1959.

These concepts in technical leadership have been validated time and again. Rabi led Drew, Zacharias, Purcell, Nordsick, Millman, Schwinger, Kellogg, Kush, and Ramsey into the MIT and Columbia Radiation Laboratories. Each of these has contributed in his own right. Hundreds of others can be listed; Lawrence at Berkeley, Shockley at Bell, etc. The multiplier effect of individual technical leadership is inealculable.

While it is recognized that these examples are of a stature above the level of concern here, the concept can be translated and is usable at a lower level of organization, and at the lower level the basis of selection would be set and appraised by a peer group that is responsive to the respective level. But even at this level it must be recognized that the leader selected cannot be superimposed on an existing organization and be expected to produce to his capability, but must be given the freedom of judgement and action necessary and concomitant with the level of expectation of results, in other words, once personnel have been hired, it is incumbent on management to supply the support, environment, and structure which will retain these personnel and allow them to grow professionally.