

# The Challenge of Success

by Bruce Murray

**O**ftentimes in recent years, Caltech commencement speakers have been members of the Caltech faculty — Feynman, Delbrück, Gray, for example. Each of them has focused on the accomplishments of hard science and the importance of high standards. I would like to complement this approach by focusing on the people of Caltech who practice and teach this hard science, who exhibit those high professional standards, and who carry out research and engineering of unexcelled quality.

Fortunately, I have a most convenient point of reference. At this very locale 13 years ago John Gardner gave the convocation address for Caltech on its 75th anniversary. He had some very thought-provoking words, which I find to be highly relevant to the present. After noting that he had spent the prior 20 years appraising the promise and performance of institutions of all kinds, he said:

... and those years have taught me to give free reign to my gratitude and my awe when I have the privilege of knowing an institution in its moment of greatness.

That phrase — “moment of greatness” — really caught my thoughts and feelings. Indeed, all of us at Caltech have shared the rare privilege of working together in an institution in a moment of greatness; that shared experience binds us together for life.

A commencement ceremony brings together some who are leaving and some who will stay. Those of us who are staying are staying to consume ourselves in the operation of this rare institution. Those who are leaving are leaving to become part of a future at which we can only guess, involved in institutional associations that, in part, haven't even been conceived. But, I think it can be useful for all of us to reflect on Caltech the institution, especially when we consider Gardner's next statement:

I don't want to alarm you by that phrase “moment of greatness,” but in the perspective of decades and centuries institutional greatness is a transitory thing.

So, 13 years later, it seems appropriate to ask: How has Caltech fared since 1966 in character and reputation? Have we remained that unique small place of the highest quality?

In terms of size, the answer is that we *have* remained unique and small. From the end of World War II until the late 1960's there was rapid growth. But the present faculty numbers only about 3 percent more than that of 1966. There are about 10 percent more freshmen and about 13 percent more graduate students, but the total number of degrees being conferred today is about the same as in 1966. The campus staff has not increased significantly in size in the last 13 years. So the campus has changed little in total number of people. There has been a modest increase in the number of employees at JPL, but that number fluctuates due to the vagaries of the space program, and there have been other times since 1966 when a comparison would have shown virtually no change at all.

In terms of the campus's physical plant, there has been a very large growth — about 40 percent increase in building space since 1966. Therefore, the campus is better housed and thus better supported for research and for education than in 1966. In the same interval, JPL space has increased about 17 percent. Over all, the campus's size has remained small, and that of the Laboratory has increased only slightly. Both are better equipped than they were then.

For another basis of comparison, consider faculty reputation and quality. That is a difficult subject to investigate in a precise way, but there are some indicators. For example, members of the National Academy of Sciences and National Academy of Engineering are elected through a very careful national process. In 1966, 32 members of the Caltech faculty, including professors emeriti, were members of the National Academy of Sciences. Today there are 49. In the case of the National Academy of Engineering, the number has gone from 7 to 28.

Another indicator of reputation in basic science is Nobel laureates. In 1966 there were two on the Caltech faculty. There are two now also who are teaching, as well as two others who have only recently retired. If we take the cumulative Nobel laureates — that is, those who have been students at Caltech as well as faculty here at the time they received the award — that number has grown from a total of 11 in 1966 to 17 at this time. I believe that together

these figures are valid evidence that the Caltech faculty is unparalleled in research reputation. Personally, I don't know of a better place to practice science. This campus is run by the faculty and, in many ways, *for* the faculty.

Another sign of the greatness of an institution is how it contributes to national leadership. The last 13 years have shown some outstanding achievements. Lee DuBridge retired in 1969 after 23 years as Caltech's President and became Science Adviser to then-incoming President Nixon. The present Science Adviser, Frank Press, spent many years here before moving to MIT. And DuBridge's successor as Caltech's President, Harold Brown, moved on after 8 years at Caltech to become the first scientist ever to head the Department of Defense, making him the second-highest ranking scientist in government. (For the highest ranking scientist currently in government, of course, we have to credit the Naval Academy!) As a matter of fact, that is a pretty scary pattern for ex-Caltech Presidents: Science Adviser to Nixon, Secretary of Defense for Carter . . . Sleep well, Murph.

Over the past 13 years, JPL has also had momentous achievements. In 1966 the first United States unmanned-vehicle surveys of the Moon were being completed, and the first probes to Mars and to Venus had just been accomplished. In the intervening 13 years, Mars has been opened up, mapped, and explored in an extraordinary manner by JPL's Mariners 6 and 7 flybys and by the Mariner 9 and Viking orbiters. The Viking lander was developed by other elements of the national space program, but the entire Viking mission operation was — and is still — run out of JPL.

In the case of Venus and Mercury, JPL's Mariner 10 opened up these planets to initial scientific understanding as well as public enthusiasm and involvement. And, of course, Voyager 1 has passed Jupiter on its way to Saturn, and Voyager 2 encountered Jupiter on July 9th of this year. It too will continue on to Saturn, and, if our luck holds, Voyager 2 may even make it to Uranus. Voyager constitutes an unparalleled mission of discovery. Quite a number of people at JPL have spent many of the last 13 years making Voyager happen.

How about the Caltech students now versus those of 1966? One good thing is that the mix is becoming more representative of our society because in 1966 there were no women freshmen and this year they will be about 16 percent of the class. In the case of graduate students, there were 4 percent women in 1966 and about 12 percent now.

An indicator of student quality is the freshman entrance exam scores. In 1966 they were incredibly high for mathematics, and they remain so. In English there are

some fluctuations year-to-year, but the scores remain very high and leave no basis for concern regarding the quality of the incoming class. What is especially significant about the continued superlative performance on the College Board's Scholastic Achievement Tests is that during the same period of time SAT scores of incoming freshmen for all U.S. college entrants have dropped conspicuously in both math and English. Caltech students have not been a part of that unhappy national pattern.

Running down the statistics I've given and reflecting on John Gardner's "moment of greatness" remark, after 13 years we can say that Caltech still is great in terms of student, staff, and faculty quality, in terms of research achievement, and in terms of its national significance. The unique formula of small campus and excellent institution still seems to be working.

As a matter of fact, you might be led to ask almost the opposite question: Isn't it remarkable that Caltech has been so *unaffected* by the turbulent events of the sixties and seventies when such resounding changes have taken place in the United States? And if you ponder that anomaly and then go on a little further in Gardner's speech, you may be troubled by the following words:

The appearance of greatness is more enduring. Reputation and tradition are effective cosmetics for a fading institution. But what is all too transitory is that fine moment when an institution is responding with vigor and relevance to the needs of its day, when its morale and vitality are high, and when it is holding itself to unsparing standards of performance.

I don't believe anyone who is a part of Caltech can have any doubt about the "unsparing standards of performance." The "morale and vitality" are high, and the "vigor and relevance to the needs of its day" probably are high also; but these things, being more subjective, are harder to assess than standards of performance.

Let me ask my question in a different way: What changes *have* taken place at Caltech in the last 13 years? Well, the faculty itself has remained small, but it's an older one and more settled. The average age has increased from 44 to 47. And if current trends continue, the average age will increase to nearly 49 in the next decade and will not return to its present level until well past the turn of the century. The percentage of tenured faculty increased from 73 percent in 1966 to a high of 84 percent in 1977. It is now at about 80 percent.

How about the formation of new educational and research programs or departments in that time? There was a burst of innovation in the late sixties. The Environmental Quality Lab was started and has become a permanent fix-

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ture on the campus. (But that “model” hasn’t been repeated, even with an important interdisciplinary subject such as energy.) The Social Science program was started also at the eve of the last decade; it’s now a widely recognized, highly respected program. Behavioral Biology was started. My own program of Planetary Science was only three years old in 1966, and we had just produced our first batch of PhD’s. It is now 16 years old and, as academic programs go, approaching middle age. The 1970’s were dominated by the flowering of bold innovations (for Caltech), stemming from the 1960’s, along with a modest level of new 1970’s innovations such as Computer Science, Applied Physics, and Cell Biology.

The questions in my mind are: Are we ready for another round of real institutional innovation comparable to the EQL and Social Science experiments? Have the necessary ferment and creative thinking taken place or just a continued maturing and aging of existing arrangements?

Another Caltech index about which we are always concerned is the percentage of federal support for the campus budget. In 1966 that was about 60 percent if we take into account all sources of funds. And that was a worryingly large percentage. Today it is still only about 60 percent. It has gone up and down as various factors have influenced the totals, but now a disturbing trend is setting in. The campus budget is now shifting steadily toward increased percentage of federal support at the rate of one-half percent per year. This is because private endowment and other non-federal funds cannot keep up with the high rates of inflation as well as can the sources of federal funds.

At JPL the average age of scientists and engineers has also increased 3 years — in this case from 38 to 41, although it has now leveled off. The average length of service is about 16 years. JPL still is the center for planetary exploration, but the pace has slowed, and national support is more precarious. This circumstance reminds me of an old cartoon from *The New Yorker* that shows Queen Isabella sitting on her throne. Columbus is kneeling in front of her, obviously pleading for money to buy the ships to search for the New World. Queen Isabella is saying a bit petulantly, “Why do you need three ships to discover the New World? Why won’t one ship do?” In fact, the Voyager mission may be the last of the two-ship U.S. missions of planetary discovery. We are down to one ship for the new missions we’re planning.

Increased age, increased degree of tenure, increased length of service, all mean that it has been longer since the people who compose Caltech were somewhere else — longer since they acquired experience in different institutional circumstances. Being more settled could mean that

there is a greater willingness to accept the status quo and to resist institutional change.

As a matter of fact, institutionally, Caltech is an anachronism. If this campus disappeared for some reason, I think it’s doubtful it would be replaced. It was a product of an expanding and optimistic private sector, back in the days when progress was spelled with a capital “P,” and Millikan’s “truth shall make you free” was implicitly scientific truth. “Free” also implied “happier.” If JPL disappeared, it would not be replaced either. It was a product of the partnership between a private university and the federal government to deal with the crisis of World War II and the Cold War days that followed.

In general, throughout the United States, most excellent institutions of science and technology are out of equilibrium with our society. This is because there once was unwarranted American faith in the perfectibility of humankind and its institutions through increased knowledge; that has given way to an unwarranted confusion as to our national and global purposes and to the role of science and technology in them.

Imagine that you are an anthropoid ecologist from Alpha Centauri, visiting the Earth in a disguised form and that you have a special interest in institutions. You might describe Caltech as a “highly specialized colonial organism, invulnerable to external or environmental change because of its extraordinary reputation, and with little evidence of internal motivation for change for the same reason.”

Caltech is so concerned with maintaining high standards and quality that it moves in a very conservative path as an institution. But I wonder if perhaps the concern for quality isn’t the main problem. Too much emphasis on any single aspect of life — even Vitamin C — can cause side effects, because other “vitamins” may be excluded. Too extreme a regimen may thwart the continual experimentation needed for evolution. Sustained success plus no growth creates a new and unfamiliar threat to Caltech (and to similar institutions). I would ask whether our greatness can continue without institutional evolution. Can evolution occur without institutional experimentation? And how can we have institutional experimentation in an era that affords little or no net growth?

In 1968 Caltech invited John Gardner back as the first recipient of the Robert A. Millikan Award. Again he challenged us to reflect on our institution in terms of the rapid technological and social changes in our country and the world, which he lumped together as “revolutions.”

The swift pace of these revolutions makes it desperately necessary that our institutions be adaptable.

When they are not, the sweep of events isolates them and dramatizes their anachronistic character. Even institutions that are fairly young, as history goes, find themselves woefully out of date. The rush of change brings a kind of instant antiquity.

These words bring to my mind another of the *The New Yorker* cartoons that say so much. This one shows an ancient landscape with a big adult brontosaurus impatiently explaining to a young, questioning brontosaurus, "Look kid, we're aware of the problems besetting our society. We're workin' on 'em."

What does all this mean for you who are leaving? You're not going to be here, so why should I take up your time talking about family matters? The reason is to urge you to reflect on what you have received from Caltech. The most important part — which you should treasure and nurture — is your ability to actually practice science, the science of Feynman and Delbrück and Gray. You are playing God's game by His rules. You are touching a tiny bit of the fabric of reality itself, and you should try to maintain the fierce standards of Caltech science and apply them to the more complex, amorphous, and critically important problems involving human beings.

But I would urge you not to accept uncritically the rest of the trappings of Caltech. We faculty and administrators are already obsolete in some ways. You must continually renew yourselves to grow beyond us, to be capable of leadership in a world we can't even envision. You must accept the challenge to try to be *complete* intellectuals, not just specialists in narrow parts of science and technology. Most of all, you must not permit yourselves to take refuge in the cultural and social myths, the prejudices, and the unexamined assumptions that we who make up Caltech necessarily exhibit. You must try to separate God's rules — that's science — from man's constraints and myths about "how things ought to be."

But what about those of us who remain? Are we doomed to a gradual decline into a genteel irrelevance? Where will Caltech be on its 100th anniversary, compared to the 75th, in its moment of greatness? I would answer, first of all, by noting that Harvard is entering its fourth century of greatness. So surely we can renew Caltech for a second century if we but accept the fact of our institutional maturity, the possibility of our renewal, and the necessity for the impetus for our change to come from within.

How can Caltech do that? We can do it by renewing and evolving our relationships with our students, our society, and our colleagues. In the area of education — particularly graduate education — we can consider how the ablest graduate students should be challenged in *breadth* as well

as depth. For example, we could give special honors and awards for those students who take a PhD in a hard science and a real, meaningful minor in a soft science, or the reverse. There are even more ambitious ways to create unique opportunities and incentives for graduate student breadth if we're willing to take institutional risk.

In the case of undergraduates, our opportunity lies in looking at them in a holistic way. We have to remind ourselves that students learn from each other and from all the other environmental factors in their existence as undergraduates. This consideration suggests greater concern over the educational and emotional significance of the total undergraduate existence at Caltech. It may be that more mixed educational experiences warrant greater emphasis. The 3-2 program — which is in effect but not much used — is one approach. And, we could encourage a year off for industrial experience or to go overseas or even to work at JPL or some place such as that, in order to create a broader set of experiences. Thus we could aim at facilitating a broader total education but still with the same high standards of quality that we now have.

In this regard, I'm encouraged because President Goldberger has expressed as deep a concern as any of the faculty over the quality of our undergraduate education. There is now a new trustee committee on student life. I think these are good omens. I think we have the beginnings of some important change here.

But how about the institution — Caltech itself? In looking outward, we must realize that our partnership with the federal government is mature. There are a lot of frustrations in it. It's not going to grow much larger in real terms, and it is not likely to improve. The new opportunities for Caltech lie in expanding its partnership with the private sector. There has been a very good recent innovation by computer scientists Ivan Sutherland and Carver Mead setting up the Silicon Structures Project in partnership with the manufacturers of semiconductors. In this instance, the industrial sector participates with both money and people, and a way has been found to combine mutually overlapping interests of Caltech with a part of the industrial sector. There is something in it for both sides. I think we have to develop other mutually beneficial partnerships.

Another approach for Caltech is to respond to the new reality for the United States — that technology transfer and development are now paramount matters of national economic security. They are just as serious to us today as was World War II weapons research to our national military security in that time period. In 1941 we had a Pearl Harbor, and, as a result, innovative and unprecedented partnerships were formed between this private university

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and the federal government. And that proved to be good for Caltech and for the United States. I think we have now entered a comparable era of national challenge. So far, however, lack of a “Pearl Harbor” to energize us nationally has made it much more difficult to make people at Caltech and elsewhere aware enough of the challenge to be motivated to experiment institutionally.

Finally, we must maximize the potential within our institution. Recently, enhanced campus/JPL activities have been developed, especially in astronomy, with the wide-field planetary camera for the Space Telescope, the Infrared Astronomy Satellite, and parts of high-energy astronomy. I think some good things are beginning to happen. But we need to push further, not just in the narrow pursuit of each individual science, but in recognition that the process of working together in different ways is in itself an important form of innovation.

Institutional change, however, ultimately depends on individual change. There cannot be lasting institutional renewal unless the people who make up the institution become renewed themselves. In that regard we have to face a re-examination of the whole concept of tenure and faculty retirement. Traditionally, the purpose of tenure has been twofold. First — and, in my view, most important — is the need to afford protection for talented individuals who should be free to comment on whatever their intellect leads them to, including what their society is doing. These individuals must have protection from political and social harassment, which is likely to arise if they are saying unpopular things. In my view, freedom of expression is the unique attribute of a modern university. However, it does not automatically follow that the only way it can be accomplished is by guaranteeing a person a job “for life,” which can mean 35 or 40 years.

The second purpose of tenure traditionally has been to afford economic stability to professors in research environments so they can carry out creative research without having to be overly concerned about their salary support running out when a particular contract ends.

Financial stability is very important, but I suspect it too can be accommodated with something less than 35- or 40-year guarantees. For example, 5-year rolling contracts might afford a realistic alternative. It is most important that tenure be used only for the right reasons and not appear to reflect a guild or elite mentality.

The tenure system affords a *disincentive* to change — both institutionally and personally — especially when combined with our faculty retirement system. Our present retirement system is satisfactory if one lives beyond 68 and can use it, but it provides very little money until then. That

mitigates against mid-career changes by our faculty. Most professors don't have enough personal net worth to easily permit mid-career changes. It's not at all clear to me that these circumstances work in the best interests of Caltech or of the individual faculty members. It denies the freedom of choice that individuals of comparable ability have in business, government, and many other professional activities. (Of course, aging professors can always be farmed out to head JPL or places like that, but we haven't that many JPLs!)

We also have to face emerging issues on the role of our research personnel who are not part of the teaching staff. How do they relate to the institution? Is the relationship a marriage, a friendship, or a transitory acquaintance? These are some tough issues that must be faced because of the national need for continuing research of the highest standards and of substantial volume here at Caltech even though there is little prospect of net growth and, therefore, new individual opportunities for some who are here on research appointments.

But Caltech has tremendous reputation and quality, so it can afford the risk of innovation. It has always been well supported because it has been unique and, thus, attracted special treatment making it possible to have an incredibly low student-to-faculty ratio here, unlike anywhere else in the United States. But we must seek our new institutional uniqueness, not merely presume that past patterns of support and activity will continue unchanged.

In summary — for those who are staying as well as those who are leaving — we all must aspire to be an elite of performance, not privilege, and to become part of the community of quantitative intellectuals, most of whom have not even yet been born. Real limits to growth are being reached globally: The whole world has to come to terms with a steady state rather than an explosively growing circumstance. Our historic circumstance is to live at that singular period when man the toolmaker faces his most promising and yet his most dangerous era, when his technical powers outstrip his social structure. Our chosen destiny must lead toward an era when quality will again rule over quantity; when man's incredible potential for greatness and achievement can unfurl free from the self-destructive tendencies so evident today.

Our primary institution is not Caltech, it is planet Earth. Our primary constituency is not our fellow scientific colleagues, it is *Homo sapiens*. All of us, those who are leaving and those who are staying, must together accept the challenge of continuous renewal so that our institutions, indeed, our world, can evolve rapidly enough to succeed. The future deserves nothing less. Godspeed, graduates! □