

ECONOMIC CLUB OF NEW YORK 18 NOVEMBER 1963

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PRESIDENT WATSON, MEMBERS OF THE ECONOMIC CLUB OF NEW YORK, DISTINGUISHED GUESTS.

I AM HONORED TO BE INVITED TO SPEAK TO YOU THIS EVENING AND TO SHARE YOUR PLATFORM WITH SECRETARY MC NAMARA.

SOME FORTY YEARS AGO THE PHILOSOPHER, ALFRED NORTH WHITEHEAD, SAID, "WHAT IS PECULIAR AND NEW TO THE 19TH CENTURY, DIFFERENTIATING IT FROM ALL ITS PREDECESSORS, IS ITS TECHNOLOGY." I DON'T KNOW WHAT HE WOULD SAY TODAY.

YET, I BELIEVE THAT THERE ARE FEW AMONG US WHO WOULD NOT AGREE THAT TODAY, AS NEVER BEFORE, SCIENCE AND TECHNOLOGY CONSTITUTE A MAJOR FORCE IN CONTRIBUTING TO AND HELPING TO SHAPE OUR ECONOMIC LIFE, OUR SOCIETY, AND EVEN OUR RELATIONSHIPS WITH MEN AND COUNTRIES THROUGHOUT THE WORLD. A MEASURE OF THIS WE SEE IN THE INCREASING NUMBER OF BILLIONS OF DOLLARS INVESTED EACH YEAR IN NEW TECHNOLOGY, BOTH FOR NATIONAL PURPOSES AND FOR IMPROVED LIVING STANDARDS FOR OUR PEOPLE. WE SEE IT IN THE ACCELERATED SEARCH FOR NEW KNOWLEDGE. WE SEE IT

IN THE MAGNIFICENT CONTRIBUTIONS OF MEDICAL SCIENCE,  
MAKING POSSIBLE LONGER AND HEALTHIER LIVES.

AN EXPERIMENTAL COMMUNICATIONS SATELLITE  
ORBITS THE GLOBE, EXCITING PEOPLE THROUGHOUT THE  
WORLD WITH THE PROMISE IT HOLDS OF CLOSER COMMUNICA-  
TIONS AND, HOPEFULLY, BETTER UNDERSTANDING AMONG  
NATIONS.

A NEW DISCOVERY IS MADE ENABLING US TO  
AMPLIFY LIGHT AND PRODUCE LIGHT WAVES OF A PURE,  
SINGLE FREQUENCY BY CONTROLLING THE ELECTRONS AND  
ATOMS IN VARIOUS MATERIALS. AND, DESPITE THE  
FACT THAT WE STILL HAVE VERY MUCH TO LEARN ABOUT  
THIS PHENOMENON, THE PUBLIC INDULGES IN ALL SORTS  
OF SPECULATIONS ABOUT WHAT THE OPTICAL MASER, OR  
LASER, MIGHT SOME DAY BE ABLE TO DO.

THESE ARE BUT INDICATIONS OF THE INCREASING  
INTEREST AND ABSORPTION BY THE PUBLIC IN THE SUBJECT  
OF SCIENCE AND TECHNOLOGY AND IN THE PART SCIENCE  
AND TECHNOLOGY PLAY IN BETTERING THE CONDITION OF  
MAN.

WITH SUCH A BACKDROP FOR OUR TIME, I BELIEVE  
IT TO BE IMPORTANT FOR MANAGERS OF ENTERPRISES VITAL  
TO OUR NATION'S ECONOMY TO CONCERN THEMSELVES WITH  
THE PROCESS BY WHICH THE SIMPLICITIES OF SCIENCE

ARE MADE USEFUL IN THE COMPLEXITIES OF SOCIETY.

LESS THAN A CENTURY AGO THE PROCESS WAS ALMOST ENTIRELY DEPENDENT ON INDIVIDUAL GENIUS -- AS IN PASTEUR'S VACCINES, IN BELL'S TELEPHONE, EDISON'S LIGHT BULB, HALL'S ALUMINUM PROCESS, BESSEMER'S METHOD FOR MAKING STEEL, AND GOODYEAR'S DISCOVERY OF HOW TO MAKE HARD RUBBER. THEIR INDIVIDUAL, DILIGENT SEARCHES FOR UNDERSTANDING AND INVENTION, COUPLED WITH PROFESSIONAL ENGINEERING TO APPLY THE RESULTS OF THEIR INSIGHT, SUFFICED FOR THEIR TIME. AND, INDEED, VAST STRIDES FORWARD IN THE BETTERMENT OF OUR STANDARD OF LIVING AND THE DEVELOPMENT OF OUR ECONOMY RESULTED FROM THEIR INGENUITY.

IN THE EARLY PART OF THIS CENTURY BEGAN, A BROADER APPROACH TO WHAT WE MIGHT CALL "ORGANIZED CREATIVE TECHNOLOGY" -- IN EXPEDITING THE GENERATION OF NEW KNOWLEDGE AND ITS APPLICATION TO NEW THINGS, NEW PROCESSES, NEW SERVICES.

WE HAVE EXPERIENCED AND CULTIVATED THIS EVOLUTION IN OUR LABORATORIES SERVING THE BELL TELEPHONE SYSTEM; AND, OF COURSE, IT IS OBSERVED IN OTHER LABORATORIES ENGAGED IN OTHER ENDEAVORS.

THIS EVOLUTION HAS DERIVED FROM A GROWING AWARENESS OF THE CONDITIONS WHICH CAN PRODUCE OPTIMUM RESULTS FROM THE NURTURE OF SCIENTIFIC RESEARCH AND ITS CAREFUL CONVERSION TO TECHNOLOGY.

WHAT ARE THESE CONDITIONS? IS SIZE IMPORTANT? I THINK IT IS ~~is~~ BUT, WHILE THERE IS PROBABLY A MINIMUM USEFUL SIZE RELATED TO ANY COMPREHENSIVE TECHNICAL CHALLENGE, ~~is~~ SHEER MANPOWER ITSELF NEVER SOLVES THE KINDS OF CHALLENGES I HAVE IN MIND.

NOR WILL DOLLARS BUY SOLUTIONS. DOLLARS ARE VERY IMPORTANT. SALARIES MUST BE ADEQUATE, LABORATORIES WELL EQUIPPED AND WELL SERVICED. BUT DOLLARS ALONE WILL NOT BUY US TECHNOLOGICAL STRENGTH -- OR A TRIP TO THE MOON.

IN THE URGENT CIRCUMSTANCES OF WORLD WAR II, IT IS ARGUED, MANPOWER AND DOLLARS PRODUCED NUCLEAR WEAPONS AND RADAR, THEY PRODUCED THE PROXIMITY FUSE, ANTIBIOTICS AND OTHER SPECTACULAR RESULTS. CAN WE NOT USE THE SAME TECHNIQUES -- THE SAME KIND OF "TEAM" EFFORTS ~~FOR~~ FOR CURRENT, HIGH PRIORITY MATTERS? I EXPECT WE CAN IN SOME CIRCUMSTANCES. BUT FOR

ANY EXTENDED PERIOD SOMETHING MORE IS ESSENTIAL AND, I BELIEVE, WE MUST SATISFY CERTAIN IMPORTANT AND NECESSARY CONDITIONS.

I SHOULD LIKE TO MENTION THREE:

FIRST, THE MOST SPECTACULAR PROGRESS IN THE APPLICATION OF SCIENTIFIC KNOWLEDGE FOR HUMAN USE TAKES PLACE IN COMMUNITIES OF GIFTED PEOPLE, INSTITUTIONS OF MEN, WORKING TOGETHER INTIMATELY BUT INDEPENDENTLY, EACH FREE TO FOLLOW HIS OWN MIND. SUCH A GROUP COMPRISES THE ESSENTIAL MECHANISM WHICH CAN BRING TOGETHER THE MANY DISCIPLINES AND KINDS OF LEARNING FROM THE MOST ABSTRACT MATHEMATICS TO THE MOST CONCRETE MECHANICS AND DESIGN. BRINGING THESE DIVERSE ELEMENTS TOGETHER IS ONE OF THE ESSENTIAL CONDITIONS. THIS NOTION OF THE COMBINATION OF THE VARIOUS DISCIPLINES OF SCIENCE, ALONG WITH THE VARIOUS BRANCHES OF ENGINEERING, IS AN INSTITUTIONAL APPROACH WHICH HAS ARISEN ALMOST ENTIRELY IN THE PAST FEW DECADES.

BUT A COMMUNITY OF GIFTED PEOPLE IS NOT ENOUGH. ALTHOUGH I MENTION IT SECOND, ANOTHER CONDITION OF AT LEAST EQUIVALENT IMPORTANCE IS THE NEED FOR A COMMON UNDERSTANDING OF PURPOSE

ON THE PART OF THE COMMUNITY SO ASSEMBLED -- A PURPOSE THAT IS SUFFICIENTLY IMPORTANT, SUITABLY BROAD, AND TECHNICALLY MEANINGFUL SO THAT GIFTED PEOPLE WILL BE INSPIRED BY IT, CHALLENGED TO HELP ACHIEVE IT, AND REWARDED BY A SENSE OF WORTHWHILE ACCOMPLISHMENT AS STEPS OF PROGRESS ARE MADE.

FROM THE TIME OF BELL'S DISCOVERY OF THE TELEPHONE THE COHESIVE ELEMENT IN THE BELL SYSTEM HAS BEEN OUR CONTINUOUS PURPOSE TO FIND AND USE EVERY RESOURCE THAT WILL CONTRIBUTE TO THE ADVANCEMENT OF COMMUNICATIONS. OURS HAS NOT BEEN A CASE WHERE TECHNICAL DISCOVERIES HAVE THEMSELVES FORMULATED THE OBJECTIVES OF THE ENTERPRISE. INSTEAD, CLEAR, SIMPLE THINKING ABOUT HUMAN NEEDS SUGGESTED GOALS OF SUCH VALUE AND CHALLENGE TO THE MIND THAT COMMUNITIES OF SCIENTISTS AND ENGINEERS WERE INTRIGUED AND WERE WILLING TO DEDICATE ALL SORTS OF SKILLS AND LEARNING IN ORDER TO ADVANCE TOWARD THESE GOALS.

THUS THE EARLY IDEA OF CONTINENT-WIDE TELEPHONY, (SUBSEQUENTLY BROADENED AND ELABORATED) IN WHICH ANY PERSON ANYWHERE IN THE NATION COULD SPEAK THROUGH HIS OWN TELEPHONE TO ANYONE ANYWHERE

ELSE, WAS A HIGHLY VISIONARY STATEMENT AT THE TIME IT WAS PUT FORWARD BY THEODORE VAIL. YET IT WAS A SIMPLE PRINCIPLE, MEANINGFUL TECHNICALLY, WHICH HAS CONSISTENTLY AND PROGRESSIVELY MOTIVATED THE WIDE RANGE OF EFFORT IN OUR LABORATORIES.

I SHOULD LIKE TO INTERJECT HERE THAT, IN STRIVING TO FULFILL OUR PURPOSE, WE HAVE BEEN TEMPTED INTO BYWAYS. AMONG THESE, COMING QUITE NATURALLY FROM OUR COMMUNICATIONS ACTIVITIES, ~~WERE~~ WERE THE IMPLEMENTATION OF THE FIRST RADIO BROADCASTING, THE REALIZATION OF SOUND FOR MOTION PICTURES, THE DEMONSTRATION OF FULL-COLOR VIDEO, AND EVEN THE DISCOVERY BY ONE ENGINEER WORKING ON TELEPHONE TRANSMITTERS OF THE PRINCIPLES NOW EMBODIED IN THE UNIVERSALLY EMPLOYED DIAPHRAGM FUEL PUMP FOR AUTOMOBILE ENGINES. IT WAS DECIDED EACH TIME, OFTEN WITH CONSIDERABLY AGONY, NOT TO PURSUE THESE BYWAYS. HAD WE PURSUED THEM THE GREAT GOALS WOULD HAVE BECOME FRAGMENTED AND THE MAIN PURPOSE OF BEING ABLE TO FOCUS A MARVELOUS DIVERSITY OF KNOWLEDGE FROM MANY FIELDS OF SCIENCE AND ENGINEERING INTO A COMMON EFFORT TOWARD A GOAL

OF OVER-RIDING IMPORTANCE FOR HUMAN USE WOULD HAVE BEEN BADLY OBSCURED.

A THIRD ESSENTIAL CONDITION IS REALLY MADE UP PRINCIPALLY OF MY FIRST TWO POINTS. IT IS THE NEED FOR STIMULATING ENVIRONMENT. SUCH AN ENVIRONMENT ALSO DEMANDS, OF COURSE, THE SURROUNDINGS AND EQUIPMENT AND ORGANIZATIONAL PATTERN IN WHICH GOOD WORK IS POSSIBLE. BUT I EMPHASIZE HERE THE IMPORTANCE OF A CLIMATE OF INTELLECTUAL CURIOSITY AND CHALLENGE AS BEING ONE OF THE NECESSARY CONDITIONS IF REAL PROGRESS IS TO BE REALIZED.

HAVING CONSIDERED CONDITIONS REQUIRED IF SCIENCE AND TECHNOLOGY ARE TO PRODUCE OPTIMUM RESULTS, I WILL MAKE ONLY A BRIEF COMMENT ABOUT THE STRUCTURE OF AN INSTITUTION SO CONCEIVED.

THE ESSENTIAL REQUIREMENT HERE IS AN ARRANGEMENT TO ASSURE AN ORDERLY FLOW AND DIRECTION OF EFFORT WITHOUT INTERFERING WITH THE INDIVIDUAL CREATIVE ABILITIES OF THE PEOPLE INVOLVED. WE HAVE FOUND THIS TO BE POSSIBLE *km* BY ESTABLISHING FUNCTIONAL GROUPS COVERING A BROAD RANGE OF SCIENCE AND ENGINEERING; THESE IN TURN SUPPORTING PROJECT GROUPS AIMED AT SPECIFIC OBJECTIVES.



BROAD AS OUR TECHNICAL ENSEMBLE IS, I SHOULD NOT LIKE YOU TO THINK THAT IT IS SELF-SUFFICIENT. WE ARE SIMPLY ONE PART OF AN ORGANIZATION WHICH REQUIRES MANY PARTS TO FULFILL THE PURPOSE WHICH I OUTLINED EARLIER.

WE WORK HAND-IN-HAND WITH THE BELL OPERATING COMPANIES AND AT&T COMPANY TO RECOGNIZE AND ANTICIPATE THE NEEDS OF COMMUNICATIONS USERS, TO CONCEIVE BETTER WAYS TO FILL THESE NEEDS, AND TO ASSURE THAT THE FRUITS OF THE LABORATORY WILL BE PRACTICAL AND EFFICIENT AND WILL PROVIDE THE BEST SERVICE. LIKEWISE, WE WORK CLOSELY WITH THE WESTERN ELECTRIC COMPANY, THE BELL SYSTEM MANUFACTURING ORGANIZATION, TO ASSURE THAT WHAT WE DESIGN IS NOT ONLY FUNCTIONALLY SOUND BUT IS TRULY PRACTICAL FOR MANUFACTURE AND, JOINTLY WITH WESTERN, TO STRIVE FOR STANDARDS OF RELIABILITY AND LOW COST WHICH ARE SUPREMELY DEMANDING.

PERHAPS I CAN BETTER ILLUSTRATE BELL LABORATORIES' FUNCTIONAL-PLUS-PROJECT APPROACH BY USING AN EXAMPLE FAMILIAR TO ALL OF YOU -- THE TELSTAR COMMUNICATIONS SATELLITE EXPERIMENTS.

FOCUSING ON OUR CENTRAL GOAL OF FINDING AND USING EVERY RESOURCE THAT WILL ADVANCE COMMUNICATIONS, ONE OF OUR RESEARCH SCIENTISTS CONCEIVED -- SEVERAL YEARS BEFORE SPUTNIK -- OF THE POSSIBILITY OF USING EARTH SATELLITES FOR RELAYING MESSAGES AND TELEVISION OVER GREAT DISTANCES, SUCH AS BETWEEN CONTINENTS. HE AND HIS ASSOCIATES DEVELOPED A PLAN OF HOW IT COULD BE DONE BY UTILIZING KNOWLEDGE THAT HAD EMERGED IN OUR LABORATORIES OVER A LONG PERIOD OF TIME. THUS IT WAS THAT, WHEN ROCKETS BECAME AVAILABLE, WE HAD THE CONCEPT, THE KNOWLEDGE, AS WELL AS THE NEW DEVICES WHICH COULD BE PUT TOGETHER TO CREATE TELSTAR.

AMONG THE THINGS WHICH HAD COME QUITE NATURALLY FROM OUR WORK OVER THE YEARS, EACH STEMMING FROM OUR CENTRAL COMMUNICATION PURPOSE AND NOW AVAILABLE FOR TELSTAR, WERE: THE TRANSISTOR, ANNOUNCED IN 1948; THE SOLAR BATTERY, IN 1954; HIGH-QUALITY ANTENNA DESIGNS GOING BACK TO THE 1920'S; A FREQUENCY-MODULATION SCHEME FOR VASTLY IMPROVING FIDELITY, INVENTED IN THE EARLY 1930'S; THE NEGATIVE FEEDBACK PRINCIPLE TO REDUCE AMPLIFIER

DISTORTION, INVENTED IN 1927; RUGGED TRAVELING WAVE TUBES; AND A VERY SENSITIVE RUBY MASER AMPLIFIER, FOR OUR GROUND STATION IN MAINE, DEVELOPED DURING THE LAST HALF-DOZEN YEARS.

THESE ESSENTIAL ELEMENTS WERE ALL AVAILABLE. OUR SYSTEMS ENGINEERS MADE THE NECESSARY AND LABORIOUS STUDIES, MATHEMATICAL ANALYSES, ECONOMIC FEASIBILITY DETERMINATIONS -- FINALLY ARRIVING AT A DEVELOPMENT PLAN FOR AN ACHIEVABLE AND WORTHWHILE PROJECT.

OUR DEVELOPMENT AND DESIGN PEOPLE ORGANIZED A PROJECT TEAM. KNOWING CLEARLY THE OBJECTIVES, ARMED WITH ANALYSES, ~~AND~~ AND WITH THE BASIC DEVICES ALREADY IN HAND, THEY BUILT TELSTAR IN A REMARKABLY SHORT TIME.

IN ALL THIS THERE WAS NO MAGIC AND VERY LITTLE THAT WAS UNIQUE. THE TECHNICAL CONCEPT SIMPLY WAS AN EXTENSION TO A DIFFERENT ENVIRONMENT OF OUR LONG-USED MICROWAVE SYSTEMS; THE PARTICULAR IMPLEMENTATION WITH APPROPRIATE NEW TECHNIQUES DEPENDED ON OUR HAVING A COMMUNITY OF GIFTED PEOPLE IN BEING, ABLE TO RESPOND TOGETHER TO THIS NEW, SPECIFIC CHALLENGE.

EARLIER I MENTIONED THE OPTICAL MASER -- OR LASER. I SHOULD LIKE TO USE IT AS AN EXAMPLE OF THE CONTINUING SEARCH FOR NEW PRINCIPLES, NEW MATERIALS AND DEVICES THAT WILL SERVE US ALL IN THE YEARS AHEAD. AS YET, THE LASER IS STILL IN THE RESEARCH STAGE. WE ARE STRUGGLING TO UNDERSTAND IT BETTER, TO CONTROL ITS ACTIONS AND THE WAVES OF LIGHT IT PRODUCES, SO THAT EVENTUALLY WE MAY BE ABLE TO USE IT IN COMMUNICATIONS SYSTEMS.

LET ME DESCRIBE IT BRIEFLY.

LASER IS A HOME-MADE WORD. L STANDS FOR LIGHT; A FOR AMPLIFICATION; THE FULL WORD STANDING FOR LIGHT AMPLIFICATION BY THE STIMULATED EMISSION OF RADIATION. IT IS A DEVICE BASED ON A NEW TYPE OF AMPLIFICATION. THE PHENOMENON OF AMPLIFICATION COMES FROM SUBJECTING THE EXCITED ATOMS TO ELECTROMAGNETIC WAVES (I.E. RADIO WAVES OR LIGHT WAVES) OF JUST THE RIGHT FREQUENCY, THUS STIMULATING THE ATOMS TO EMIT THE ENERGY STORED IN THEM.

THE FACT THAT ATOMS EMIT RADIATION IS A COMMONPLACE. THE EXCITED NEON ATOMS IN THE NEON

SIGNS WE SEE EVERY DAY DO JUST THAT. BUT NORMALLY THEY RADIATE THEIR CHARACTERISTIC RED LIGHT IN RANDOM DIRECTIONS AND AT RANDOM TIMES AND THE RESULTING LIGHT IS INCOHERENT (A TECHNICAL TERM MEANING JUST WHAT YOU MIGHT EXPECT -- A JUMBLE/).

THE TRICK IS TO FIND THE RIGHT ATOMS, WITH THE RIGHT INTERNAL STORAGE MECHANISMS AND ARRANGE AN ENVIRONMENT IN WHICH THEY CAN ALL COOPERATE -- TO GIVE UP THEIR LIGHT AT THE RIGHT TIME AND ALL IN THE SAME DIRECTION.

WE NOW HAVE MANY COMBINATIONS FOR ACHIEVING THIS RESULT. THERE ARE IN FACT MORE THAN 100 SUCH "SYSTEMS", SOME SOLID, SOME USING GASES, EACH PRODUCING WAVES OF A CHARACTERISTIC FREQUENCY. ONE SUCH SYSTEM USES A SIMPLE ROD OF RUBY (WHICH IS ALUMINUM OXIDE CONTAINING SOME CHROMIUM ATOMS). THE ENERGY PREVIOUSLY STORED IN THE ELECTRONS OF THE CHROMIUM ATOMS, BY INTENSE ILLUMINATION, IS EMITTED UNDER THE STIMULUS OF A WAVE WHICH BOUNCES BACK AND FORTH FROM ONE END OF THE ROD TO THE OTHER. FROM ONE END OF THE ROD, WHICH IS ONLY PARTIALLY REFLECTING, AN INTENSE BEAM OF AMPLIFIED LIGHT EMERGES.

AND THE LIGHT HAS THESE PROPERTIES: IT IS ESSENTIALLY PURE, OF A SINGLE FREQUENCY (WITHIN ONE PART IN A BILLION BILLION); INSTEAD OF MAKING AN INCOHERENT JUMBLE THE WAVES ARE NOW COHERENT -- I.E. THEY COOPERATE WITH EACH OTHER, AND THE WAVES MAKING UP THE LIGHT BEAM, AS IT EMERGES FROM THE LASER, ARE AS NEARLY PARALLEL AS NATURE ALLOWS.

WHAT ARE A FEW OF THE CONSEQUENCES? IN CONTRAST TO THE UNCOOPERATIVE JUMBLE OF LIGHT WAVES FROM, SAY, A CONVENTIONAL ELECTRIC LIGHT BULB, BEAMS OF COOPERATIVE WAVES FROM A LASER CAN BE FOCUSED TO SUCH A FINE POINT THAT TEMPERATURES ARE PRODUCED EXCEEDING BY MANY TIMES THE TEMPERATURE OF THE SUN. (THE STANDARD LABORATORY STUNT IS TO BURN A FINE HOLE THROUGH A STACK OF RAZOR BLADES IN 1/1000 OF A SECOND.) USES ARE ALREADY APPARENT IN MICRO-MACHINING, IN WELDING AND IN EYE SURGERY.

I HAVE NO DOUBT THAT USES WILL BE FOUND IN CONTROLLING CHEMICAL AND BIOLOGICAL REACTIONS FOR MOST SUCH REACTIONS ARE VERY SENSITIVE TO ELECTROMAGNETIC FREQUENCIES WELL WITHIN THE RANGE OF THESE NEW DEVICES.

BUT OUR INTERESTS ARE IN THE CRAFTS OF COMMUNICATION. PURE ELECTROMAGNETIC WAVES, E.G. RADIO WAVES OF THE SORT THAT NOW CARRY THOUSANDS OF TELEPHONE CHANNELS, AND TELEVISION, ACROSS THE COUNTRY OSCILLATE AT 4 TO 6 THOUSAND MILLION TIMES PER SECOND. THE PURE WAVES PRODUCED BY THE LASER ARE THE SAME KINDS OF WAVES, BUT THEY ARE CALLED LIGHT WAVES AND THEY OSCILLATE 10,000 OR MORE TIMES FASTER THAN OUR CROSS-COUNTRY RADIO WAVES. IN THEORY, THIS MEANS: 10,000 TIMES AS MANY TELEPHONE OR TELEVISION CIRCUITS -- PROVIDED THAT WE CAN FIND WAYS TO CONTROL AND MANIPULATE AND USE THESE WAVES AND DO SO ECONOMICALLY. THIS ALSO MEANS FINDING WAYS TO KEEP AWAY FROM FOG, WHICH HAS ALWAYS BEEN NOTORIOUSLY DIFFICULT FOR LIGHT TO PENETRATE.

WE DON'T KNOW WHEN THE PRECISION CONTROL ESSENTIAL FOR COMMUNICATIONS CAN BE ACHIEVED. BUT WE EXPECT TO LEARN HOW AND AT WHAT COST IN THE NEXT FEW YEARS -- BEFORE THE NEED IS WITH US.

DR. CHARLES TOWNES (THEN AT COLUMBIA UNIVERSITY), WHO CONCEIVED THE MASER PRINCIPLE, HAD THIS TO SAY: "... THE MASER EPITOMIZES THE

GREAT CHANGE THAT HAS RECENTLY COME OVER THE CHARACTER OF TECHNOLOGICAL FRONTIERS. IT WAS WORKED OUT AND PREDICTED ALMOST ENTIRELY ON THE BASIS OF THEORETICAL IDEAS... . THIS IS NOT AN INVENTION OR DEVELOPMENT WHICH COULD GROW OUT OF A BASEMENT WORKSHOP, OR SOLELY FROM THE EDISONIAN APPROACH OF INTUITIVE TRIAL AND ERROR; IT IS RATHER A CREATURE OF OUR PRESENT SCIENTIFIC AGE WHICH HAS COME RATHER COMPLETELY FROM MODERN PHYSICAL THEORY."

THE GREAT FLOWERING OF PHYSICAL THEORY OF THE PAST FEW DECADES AND THE STEADY APPLICATION OF THIS KNOWLEDGE TO NEW MATERIALS AND NEW THINGS HAS PUT WITHIN OUR GRASP THE MEANS TO DO ALMOST ANYTHING WE WANT TO DO.

THE CHALLENGE FOR MANAGERS TODAY IS TO DECIDE CAREFULLY AND CLEARLY WHAT THEY WANT TO DO, WHAT BROAD AND IMPORTANT AREAS THEY WANT TO CULTIVATE, WHAT THEY WANT THEIR ENTERPRISE TO BE A DECADE OR TWO IN THE FUTURE.

PHYSICAL THEORY AND NEW THINGS, MATHEMATICS, MECHANIZED LOGIC, AND THE ARRAY OF NEW ANALYTICAL TOOLS, CAN THEN BE INVOKED TO FURTHER THEIR ENTERPRISE.



AND I WOULD HOPE THAT IN MORE AND MORE AREAS,  
BROAD AND MEANINGFUL GOALS WILL BRING TOGETHER THE  
RELEVANT COMMUNITIES OF GIFTED PEOPLE WHO CAN WORK  
TOGETHER ON THEM -- TO INSURE THAT IN THE LONG RUN  
WE ARE NOT OUTDISTANCED BY OTHERS WHO HAVE FOUND  
OR MAY FIND SUCH SOLUTIONS.

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