Diurnal Variation of Stratospheric Chlorine Monoxide: A Critical Test of Chlorine Chemistry in the Ozone Layer

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Abstract. *This article reports measurements of the column density of stratospheric chlorine monoxide and presents a complete diurnal record of its variation (with 2-hour resolution) obtained from ground-based observations of a millimeter-wave spectral line at 278 gigahertz. Observations were carried out during October and December 1982 from Mauna Kea, Hawaii. The results reported here indicate that the mixing ratio and column density of chlorine monoxide above 30 kilometers during the daytime are ~ 20 percent lower than model predictions based on 2.1 parts per billion of total stratospheric chlorine. The observed day-to-night variation of chlorine monoxide is, however, in good agreement with recent model predictions, confirms the existence of a nighttime reservoir for chlorine, and verifies the predicted general rate of its storage and retrieval. From this evidence, it appears that the chlorine chemistry above 30 kilometers is close to being understood in current stratospheric models. Models based on this chemistry and measured reaction rates predict a reduction in the total stratospheric ozone content in the range of 3 to 5 percent in the final steady state for an otherwise unperturbed atmosphere, although the percentage decrease in the upper stratosphere is much higher.*

Chlorine monoxide (ClO) has for some years been recognized as a key tracer of the stratospheric ozone depletion cycle arising from natural and anthropogenic injection of chlorine-containing compounds, principally halocarbons, into the atmosphere (*1*, *2*). The reactions

$$O_3 + Cl \rightarrow ClO + O_2 \quad (1)$$

and

$$ClO + O \rightarrow Cl + O_2 \quad (2)$$

constitute the catalytic cycle by which chlorine atoms convert ozone, O_3, to diatomic O_2.

There is a strong diurnal variation expected in the concentration of ClO. After the recombination of atomic oxygen at sunset, reaction 2 ceases. At night, ClO is believed to combine in a three-body reaction with NO_2 to form chlorine nitrate,

$$ClO + NO_2 \xrightarrow{M} ClONO_2 \quad (3)$$

which is thought to be the dominant reservoir of chlorine in the absence of sunlight. During daylight hours, free chlorine is again produced from this reservoir by the photolysis of chlorine nitrate:

$$ClONO_2 + h\nu \rightarrow Cl + NO_3 \quad (4)$$

The rate of nighttime removal of ClO via reaction 3 is dependent on the NO_2 concentration and the total density, both of which decrease with altitude above 30 km: thus high-altitude ClO is expected to last through the night, while ClO at lower levels (altitude $\lesssim$ 35 km) disappears. Earlier measurements by in situ resonance fluorescence (*3*), infrared heterodyne spectroscopy (*4*), balloon-borne (*5*) and ground-based (*6*) millimeter-wave spectroscopy have established the presence, approximate quantity, and vertical distribution of daytime stratospheric ClO. A more critical test of the full complex of reactions of stratospheric chlorine may be obtained from measurements of the diurnal variation of ClO. Such observations avoid the complications and uncertainties introduced by vertical and lateral transport and long-term seasonal trends. Earlier balloon-based millimeter measurements over a limited portion of the diurnal cycle have shown a decrease in ClO at sunset and an increase after sunrise (*5*). In this article we present a complete diurnal record of ClO variation, with a time resolution of 2 hours, acquired by ground-based remote sensing of millimeter-wave line emission.

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Observations of Emission Lines

The ClO molecule has millimeter-wave rotational spectral lines spaced approximately every 37 GHz. We have reported measurement (*6*) of the line at 204.352 GHz from the $J = 11/2 \rightarrow 9/2$ levels. Our current measurements are based on the $J = 15/2 \rightarrow 13/2$ transition at 278.630 GHz. We use a cryogenically cooled millimeter-wave heterodyne mixer receiver with a noise temperature of 1100 K, approximately 2½ times more sensitive than our earlier detector (*6*). Use of this more sensitive detector, combined with an increase by a factor of 2.4 in the theoretical line intensity for the higher frequency 278-GHz line as compared with the 204-GHz line, has led to a sixfold increase in observational sensitivity. For a fixed signal-to-noise ratio, the required measurement duration is reduced by about a factor of 6^2 or 36, allowing a relatively high time resolution to be achieved. The "back-end" spectrometer consists of a filter bank with 256 channels, each with a bandwidth of 1 MHz. The measurement technique, calibration method, and instrumental configuration described earlier (*6*) remain unchanged.

Our observations were carried out at the summit of Mauna Kea, Hawaii (elevation, 4250 m; latitude, 19.5°N) during two periods, from 8 to 11 October and from 9 to 16 December 1982. The atmospheric water vapor content, which dominates the tropospheric absorption of stratospheric emission lines at millimeter-wave frequencies, was very low and generally stable around the clock during these observation periods (*7*).

In the following discussion, we present emission intensities as brightness temperatures in kelvins. This custom, commonly used in radio astronomy, is derived from the Rayleigh-Jeans approximation for blackbody radiation, in which emitted power per unit frequency is linearly proportional to temperature. All intensities represent the values that would be observed if one were looking through one stratospheric air mass toward the zenith after removing the effect of tropospheric attenuation.

In Fig. 1, we present a sample of midday (1230 to 1630) and nighttime

for the development of new products.

That picture represents a misunderstanding. Although MITI does indeed sponsor R & D programs, such as the highly publicized ones on integrated circuits and the fifth-generation computer, the R & D tends to be basic and engineering research. In the United States, such R & D efforts are centered in our universities.

The commercial R & D successes of Japan, as opposed to efforts to develop the underlying technologies, have been driven not by MITI but by Japanese industry, even in integrated circuits. The participants in the MITI-sponsored cooperative integrated circuits program went back to their own laboratories to develop the actual commercial 64K random access memory chips that have been so successful in the marketplace. Oki Electric, the fastest growing Japanese producer of 64K chips and the first Japanese company to test a 256K chip, did not even participate in the MITI program.

The Japanese government, which has played an important role in promoting its industries' fortunes through such means as protectionist trade policies, has not been a significant force in commercial technology selection and development. The successes of Japan in businesses based on advanced technology are mainly the result of smart, persistent industrial R & D management. Private corporations in Japan make long-term R & D commitments to relatively narrow areas. They pick a target, such as video recorders, assemble large teams to pursue that target, and stick with it for as long as is necessary to bring a winning product to market. They do not try to cover the R & D waterfront, and they do not back out if the payoff is not immediate. They also practice a technique that I call "innovation by experiment," whereby they put a product out on the market, even in imperfect and sometimes expensive form, and learn from the customers how to improve it. And finally, they are aggressive in acquiring, improving, and implementing technology that they did not develop.

These strategies do not explain all of Japan's success in commercial technology, but they do indicate that the real source of that success is Japanese industry. Also, they underscore the lesson that we should learn from Japan: that the selection of the product technology and its development is best left to the people intimately familiar with the technologies and the markets. Technology selection and development should not be managed from afar.

Creating Conditions for Innovation

What role should the U.S. government play with respect to R & D? That role is not to manage technology-based commercial innovation but to create the conditions for such innovation. The government should provide an encouraging and supportive environment and infrastructure within which industries select and develop commercial technology.

There are many features of such an environment that deserve attention: a favorable tax climate exemplified by R & D tax credits, by extension of those credits to software, and by fast depreciation of R & D equipment; modified antitrust laws that encourage cooperative R & D and limit damages for civil violations; export control laws and regulations that do not disrupt the interchange of scientific and technical information that is so vital to the progress of technology; and immigration laws that permit outstanding foreign scientists to remain in the United States to do R & D.

Support for University Research

The most important role for government in creating the conditions for commercial innovation is to support universities in their efforts to generate research and provide manpower. The most crucial issue we face is a lack of skilled manpower, a shortage of faculty in universities for training that manpower, and a deteriorating research capability in our great universities because of the shortages of both faculty and modern equipment for instruction and for research.

American industry today simply cannot get enough of the people it needs in such fields as microelectronics, artificial intelligence, communications, and computer science. The universities are not turning out enough R & D people in these areas, or enough research faculty. There is little that private companies can do about this. We contribute to the support of universities, but industry will never be able to meet more than a small fraction of university R & D funding needs. Even after a decade of steadily increasing industry support for universities, industry provides only about 5 percent of total university R & D funding. Congress is considering additional incentives for industry support of universities, but the fact remains that the primary responsibility for ensuring a strong, healthy academic research system and thereby for providing an adequate supply of research and skilled people must rest with the federal government.

There is wide agreement that the federal government should support the universities, and, in fact, federal basic research obligations to universities and colleges, measured in constant dollars, have grown by more than 25 percent over the past 3 years. But this is only a start in filling the needs. Department of Defense funding of basic research, for example, has only in the past 2 years returned to the level, measured in constant dollars, that it was in 1970. The Defense Department has traditionally played a vital role in supporting basic university research. A time of rapid expansion of the defense budget is no time to abandon that tradition.

Universities have had to compete with the national laboratories for the Department of Energy's research dollars. When research is funded at a university, not only does the research get done, but also students are trained, facilities are upgraded, faculty and students get more support, and thereby better faculty and students are attracted. Moreover, the students that go into industry help in the transition of advanced research into concepts for industrial innovation. When the same research is funded at a national laboratory, most of the educational dividends are lost.

Universities should not have to compete head on with national laboratories for mission agency funds. Unless the national laboratory will do a substantially better research job, the university should get the funds. The same holds for government funding of research in industry. Those funds that advocates of industrial policy propose to invest in government-directed industrial R & D would normally be much better spent in universities, unless there is a special reason why an industrial laboratory can do it much, much better.

I am not proposing that we simply throw money at universities. We need to be selective. To borrow a phrase from the industrial policy advocates, the government should stress the growth of "sunrise science and technology." Unlike the targeting of sunrise industries, the targeting of sunrise—that is, fast moving—areas of research can be done. We can identify these technologies, even if we cannot specify in advance precisely what products or industries they will generate. But we are not doing this as well as we can and should. In microelectronics, for example, a study by the Thomas Group, a Silicon Valley consulting firm, concludes that government support of university microelectronics programs totaled only about $100 million between 1980 and 1982. To put that into

tive) from that of 17 with small-cell lung carcinoma (15 positive) is striking (see Table 1). Both cancers have common ancestry, but the former is of comparatively low malignancy and the latter is extraordinarily malignant.

5) While patients with carcinoma generally showed cellular and humoral immune responses to carcinoma-associated T antigen, the humoral response was stimulated preferentially by tubular and early lobular breast carcinomas, which had T activity comparable to other carcinomas. Significantly, these carcinoma types have a favorable prognosis among breast carcinomas (*8, 54*).

The Tn/anti-Tn system may complement the T/anti-T system in elucidating aspects of the pathogenesis of carcinoma and in early diagnosis. While the link between Tn and carcinoma has been known for a decade (*10*), this system has not been studied in the present context. Research is complicated by the usually low concentration of anti-Tn. Tn's immunodominant structure, GalNAc-α, is also the dominant part of the blood group A and Forssman haptens, which may prevent some anti-Tn immune responses. Furthermore, Tn antigen is not readily obtainable from healthy tissues (*7*). There are, however, some highly instructive experiments by nature herself that show not only how unmasked Tn arises in hematopoietic stem cells, usually persisting indefinitely without malignant change, but that Tn, the epigenetic sequela of a rare, benign, somatic mutation, occasionally precedes and then accompanies leukemia, disappears upon chemotherapy-induced remission, and reappears in relapse (*66*).

Conclusion and Prospects

The studies described here have revealed, in a large number of carcinoma patients, a close link between malignant transformation and early, persistent changes in common carcinomas: unmasked precursor antigens T and Tn, that allow the patient's immune system to qualitatively differentiate carcinoma from noncarcinoma.

On rare occasions, demonstrable T and Tn antigens occur in premalignant lesions, which may either remain that way permanently or progress to frank malignancy. Some tissues with such changes are accessible to longitudinal study and thus aid in determining the decisive point of malignant transformation. This approach may be facilitated by manipulation of immune responses, as well as by locating incipient carcinomas with labeled mono- and polyclonal anti-T and anti-Tn reagents (*25, 26, 67*) [but see the introduction and (*27*)]. Our monoclonal antibodies to T and Tn were generated by desialylized human O erythrocytes. We obtained three relevant specificities: anti-T, anti-Tn, as well as a specificity directed toward a moiety shared by T and Tn haptens (*67*). The three types of antibodies reacted strongly and specifically with carcinomas in immunohistochemical analyses of surgical specimens but less well in antibody absorption studies (*27*).

Our recent observation (*68*) in carcinoma patients, but not healthy persons, of a significant increase in lymphoid cell cytolytic activity against target cells with surface-exposed T and Tn antigens supports T and Tn's importance in the malignant process—especially since there was often a concomitant decrease in natural killer cell activity. The findings discussed here, although they are in an emerging phase, indicate that uncovered T and Tn antigens endow the carcinoma cells with a multitude of novel functions. These functions may be fundamental to the multistep processes of invasion and spread of carcinoma, and clearly have a profound, measurable effect on the tumor bearer's immune system. T antigen is likely to be a powerful probe in early carcinoma detection.

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computer scientists are more aware of the potential of the present systems and are willing to put more effort into using them, while pure scientists, for whom the computer is another tool, have a lower level of pain. If this is the case, it may be only a matter of time before everybody operates in the same mode. However, one can make the following observation: scientists, either in the laboratory or in computing, have shown that they will push their systems or tools to the limit in order to get to the results. In computing they are willing to learn to program in machine language if that gives the performance they need for a specific problem. We are now seeing physicists developing and building their own special-purpose calculating machines at a great cost in time and effort. In the laboratory it is common for scientists to take commercial instruments apart and rebuild them to improve performance, again at a great cost in time and effort.

In our laboratories, pure and applied scientists have access to the same facilities, but their patterns of collaboration are very different. It may well be that we are dealing here with subtle but strong cultural factors. It is easy to develop theories of why this is so, but it is difficult to decide one way or the other. This is a fascinating and important subject but more work, and perhaps more experience, is required to understand the reasons. Similar questions arise in connection with other fields that have proved intractable. For example, will education, that crude process in the classroom that has withstood every technical assault for the past 2000 or 3000 years, finally crumble before the impact of electronic progress? Some people think so and have projected that the interaction of computers with instruction will do it, but still we do not know. Will the availability of terminals in the home, the ability to program at home, and the ability to interact with others over wires, over glass, or possibly through satellites fundamentally change the working patterns of people? That is certainly possible, and again we do not know. Our inability to understand and predict the qualitative effects of computer technology is great. But even the straight-line projection, from what we have experienced to what we can reasonably expect to be the impact on science, is impressive.

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Protection of Plant Varieties and Parts as Intellectual Property

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The coming of age of the biological sciences has raised new questions about the protection of technology under the intellectual property laws. Intellectual property, as opposed to tangible property such as real estate or personal property, includes subject matter that is protected by patents, trademarks, copyrights, trade secrets, and more recently, patent-like plant variety protection for varieties reproduced by seed. The protection of intellectual property is not a new concept since its availability can be traced back to Greece as early as 200 B.C. (*1*). However, because the rewards for intellectual property have been high, the requirements for obtaining it have also been quite high. It is the question of what must be given in exchange for patent protection, together with the question of what scope should be given to such protection, that creates many problems in patent law. Nowhere is this more evident than in the protection of plant varieties and their parts.

The importance of protecting plant varieties is evidenced by the number of countries that have passed plant breeders' rights legislation and by the formation of the International Union for the Protection of Plant Varieties (UPOV) (*2*). UPOV administers the treaty that, among other things, requires member states to provide the same rights to plant breeders of other member states as it provides its own nationals.

Protecting Intellectual Property

Intellectual property is protected in two primary ways. The first is by statutory grants such as patents, trademarks, and copyrights. The second is by maintaining the subject matter a trade secret. Unlike patents, trademarks, and copyrights, which are mandated by federal statutory law, trade secret rights arise primarily from state court decisions or laws.

Trademarks are used to distinguish one's goods from those manufactured by others. They indicate the source of goods. The mark can be a word, symbol, name, device, or combination thereof. Examples include the Xerox, Coca-Cola, and Kodak brands.

Copyrights protect the manner of expression but not the ideas embodied in the expression. Examples are books, music, operas, maps. A copyright can only prevent others from copying the mode of expression. Independent creation is not an infringement of the copyright.

Utility (general) patents exclude others from making, using, or selling the invention and actually protect the embodied idea. They do not necessarily mean that the patentee can use his invention because it could be dominated by another patent. To be patentable the invention must be useful, novel, and unobvious (unobviousness requires a step that is not merely a technique within the scope of a person with ordinary skills in the art).

Plant patents provide protection for plant varieties that are reproduced asexually (by budding, grafting, tissue culture, and so on). Uncultivated and tuber-propagated plants (such as Irish potatoes and Jerusalem artichokes) are excluded from protection.

Plant variety protection provides patent-like protection for plant varieties re-

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produced by seed. Fungi, bacteria, and first-generation hybrids are excluded from protection.

Trade secret law protects against unauthorized appropriation or disclosure of the proprietary information.

The systems for granting intellectual property rights vary. The two broad classes are registration and examination systems. Protection under a registration system is easier to obtain because usually the only requirement is that of either novelty or originality. Novelty requires that the subject matter be different from existing subject matter that is known. The extent of the difference is irrelevant. Originality means that the applicant created the subject matter. In other words, the subject matter was not copied. Examples of registration systems are the U.S. copyright, trademark, and plant variety protection schemes.

Protection under an examination system is more difficult to obtain because there is generally a requirement for unobviousness or an "inventive step" as it is referred to in some foreign patent laws. Unobviousness requires a step or result that is beyond that expected of a person with ordinary skills and knowledge in the field of the invention for which protection is being sought. Examples of examination systems are the patent systems of the United States, United Kingdom, Federal Republic of Germany, the Netherlands, and Japan. Patents obtained under examination systems generally provide a broader range of protection than those obtained under registration systems.

The claims of an invention define what is protected. The claims can be analogized to a real estate deed. Instead of using distances and landmarks the claims contain works that outline the boundaries of the invention claimed. For example, Fig. 1 shows the boundaries of a claim to a group of chemical compounds. The boundaries surround any use of the compounds and any method of making them. Therefore, if someone else either discovers a new use of the compounds or a new method of making them, he will have to cross the boundary to compound A to practice the new use or method. Crossing the boundary without the owner's permission is a trespass or, in intellectual property terms, an infringement.

Protecting Plant Varieties and Their Parts

Plant varieties. It is established that plant varieties that are reproduced asexually can be protected under the Plant Patent Law, the Townsend-Purnell Act of 1930 (*3*). It is also clear that plant varieties that are reproduced by seed are protectable under the Plant Variety Protection Act of 1970 (*4*). It is not so clear, however, whether asexually or sexually reproducible plant varieties can be protected under the general patent statute. Even though patents issued under the general patent law (*5*) have covered material containing living matter, the general patent law has most often been applied to inanimate subject matter. As a matter of fact, a great body of technology in which living material was utilized to produce chemicals provided the fertilizer for the production of steroids and antibiotics. However, a great deal of controversy arose when attempts were made to claim living organisms per se. Part of this controversy culminated in the case of *Chakrabarty* v. *Diamond, Commissioner of Patents and Trademarks* (*6*), in which the U.S. Supreme Court held that the fact that the claimed invention encompassed living matter did not preclude general patent protection. Specifically the Court held that the important fact in determining whether or not subject matter is patentable subject matter is whether or not there has been human intervention. *Chakrabarty* involved claims to certain human-modified microorganisms that were capable of "eating" oil. The case did not change the criteria of patentability (usefulness, novelty, and unobviousness). The Court specifically ruled on what was patentable subject matter. In other words, before the criteria of usefulness, novelty, and unobviousness can be applied to an invention it must first meet the criteria of being patentable subject matter.

Answering the question of whether the general patent statute can be used to protect plant varieties that are also protectable under the Plant Patent Law or the Plant Variety Protection Act requires a considerable amount of statutory construction. Statutory construction is a procedure used to interpret laws. One of its objectives is to determine which law among several laws dealing with the same subject matter is applicable when the laws conflict. Although such an analysis is beyond the scope of this article (*7*), it is clear that some thought will have to be given to whether or not there should be different treatment of food crop varieties as opposed to nonfood crop plant varieties. For example, the Plant Variety Protection Act contains express provisions for research (experimental use) and crop exemptions, whereas the general patent statute contains no such provision. Since the Plant Variety Protection Act was an attempt to correct the inequity of there being no patent-like protection for seed-reproduced plant varieties and since many of the varieties reproduced by seed are food crops, did Congress, by providing expressly for a research and crop exemption, articulate a different policy for food crop varieties than other plant varieties?

Plant parts. Plant patent and plant variety protection laws provide for the protection of plant varieties, that is, whole plants. But how do we protect their parts? This question has to be analyzed from two perspectives. First, if protection of the whole plant is obtained, are parts of the plant also protected? Second, is it possible to protect parts of plants without protecting the whole plant?

The question of whether protection of plant parts is obtained when a plant patent is granted has received some attention, especially in the area of cut flowers. The problem with cut flowers is that a plant can be purchased in the United States and taken to a country where there is no plant variety protection; the variety is then reproduced and the flowers are cut and imported back into the United States. The question here is whether it is an infringement of the plant patent to so sell the import under section 337a. One view is that a plant

Summary. In view of the Supreme Court decision in *Chakrabarty* v. *Diamond, Commissioner of Patents and Trademarks*, it is possible that plant varieties can be protected under three different U.S. statutes: the Plant Variety Protection Act, the Plant Patent Law, and the General Patent Law. The Plant Variety Protection Act protects varieties that are reproduced by seed, whereas the Plant Patent Law protects varieties reproduced asexually. Varieties, irrespective of how they are reproduced, could be patentable under the General Patent Statute. It is not clear whether parts of plants can be protected by grants under the Plant Patent Law or Plant Variety Protection Act and it is possible that they will be best protected under the General Patent Statute and by maintaining them as trade secrets. Only time will show whether the existing statutes are sufficient to provide both guidance and adequate protection or whether changes in the law will be required.

ute, it is probable that the disclosure requirements can be met by depositing seeds or other reproductive material for those varieties.

The Plant Variety Protection Act. It is already a requirement of the Plant Variety Protection Act that a sample consisting of 2500 seeds of the variety to be protected be deposited at the National Seed Laboratory at Fort Collins, Colorado. However, many questions linger with respect to depositing microorganisms or seeds. If the seed or microorganism mutates, are the requirements of reproducibility met? Is the mutant itself protected? Does the claimed process include use of the mutant?

To be protectable under the Plant Variety Protection Act a variety must be novel (*13*) and the right to the variety must not be precluded by the activities set forth in the section that defines the right to plant variety protection (*14*). A variety is novel under the Act if it is distinct, uniform, and stable. If a variety differs from all prior art varieties by one or more morphological, physiological, or other characteristic then it meets the criterion of distinctness (*15*). The degree to which a characteristic must differ to be distinct has not been addressed by either the Plant Variety Protection Office (PVPO) or the courts. This question has been raised by the International Union for the Protection of New Varieties of Plants (UPOV) under the categorization of minimum distance.

A variety is uniform if its characteristics can be described and predicted and if they are commercially acceptable (*16*). In the case of *In re Waller* (*17*), PVPO had to consider an application in which the question of uniformity was involved. In reversing a denial of protection on the grounds of lack of uniformity, the secretary of agriculture held that PVPO could not deny protection for a dahlia solely on the ground that it did not have a uniform flower color "if the variations in flower color are describable, predictable and commercially acceptable" (*17*, p. 7).

The requirements of stability (*18*) are met if the variety's main and distinctive characteristics remain unchanged when it is reproduced by seed. While the definition of stability has not been specifically addressed by either PVPO or the courts, it has been addressed implicitly by PVPO because the denial of the application by PVPO in the *Waller* cases was on the ground that it did not meet the requirement of uniformity and stability (*16*).

Difference between food and nonfood crops. Both the Plant Patent Law and the Plant Variety Protection Act provide protection for food and nonfood crops. However, except for fruits and nuts, most nonfood crops have been protected under the Plant Patent Law, whereas most food crops have been protected under the Plant Variety Protection Act. This is probably more historical than by design. The flower nursery industry, whose primary concern is with ornamental varieties, was a strong proponent of the Plant Patent Law, whereas passage of the Plant Variety Protection Act was strongly supported by the seed industry.

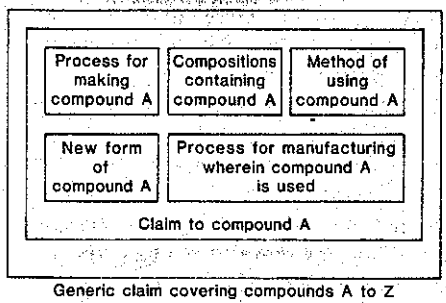

Fig. 1. Boundaries of a claim to a hypothetical group of chemical compounds. Compositions containing compound A include combination products having more than one ingredient.

As pointed out above, when the Plant Patent Law was enacted it was felt that the only way to reproduce varieties true to form was by asexual reproduction. Most ornamental plants (roses, chrysanthemums, and so forth) are reproduced asexually. They form the bulk of those plants covered by plant patents. Since most food crops are reproduced by seed, they cannot be protected by plant patents unless they are subsequently reproduced asexually. Because the technology has not yet developed to the point that most seed-produced crops can be produced more efficiently by asexual reproduction, food crops will probably continue to be protected under the Plant Variety Protection Act except when it is advantageous to attempt to do so under the general patent statute.

Protection of plant varieties under the general patent statute will raise some questions. One of the first is the question of experimental (research) use. Under the general patent statute there is no express provision for experimental use. However, a very narrow exception has evolved from case law. This exception excuses what would normally be considered infringing acts on the grounds that the acts were committed to satisfy scientific or philosophical curiosity. Acts have also been excused as being experimental on the grounds that they are considered to cause so little damage to the owner of the patent as to be meaningless. The Plant Variety Protection Act provides an express provision for a "research use" exception to infringement (*19*). Therefore, conflict could arise if a general patentee would attempt to prevent others from conducting research experiments with a protected variety. A question giving rise to the conflict is whether Congress expressed a public policy against suing researchers for infringement under the Plant Variety Protection Act that would override any rights under the general patent statute.

Another exemption that could create problems for the general patentee is the Farmers' Crop Exemption (*20*). This exemption gives a farmer who purchases a protected variety the right to use the variety to reproduce seed for production or use on his farm or to sell seed reproduced from the purchased seed. The right of a farmer to do this would appear to conflict with the provision under the General Patent Law under which the purchaser of a patented item can repair it but cannot reconstruct it. Also, at least one court has held that the Farmers' Crop Exemption does not entitle a farmer to promote or advertise the protected variety for sale (*21*).

Another difference between the General Patent Law and the Plant Variety Protection Act is that the former provides for compulsory licenses and the latter does not. Under the compulsory license provision the secretary of agriculture can permit others to produce a protected variety if he finds that to do so will be in the national interest. This difference, however, may be one of form rather than substance since the U.S. government (or a court when there has been an antitrust violation) can, under its powers of eminent domain, authorize others to use the patentee's invention. The patentee then has a remedy against the government in the U.S. Court of Claims (*22*).

Breadth of Protection

Two of the most interesting questions concerning the protection of plant varieties are (i) how different will the new variety have to be from the closest old variety in the prior art to obtain protection and (ii) how different will a variety have to be from a protected variety without infringing that variety?

The Plant Variety Protection Act. Many people in the seed industry contend that once a difference has been identified between a new variety and

sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made."
6. *Chakrabarty* v. *Diamond*, 206 *U.S. Pat. Q.* 193 (U.S. Supreme Court, 1980).
7. A. Diepenbrock, C. Neagley, D. Jeffrey, *Am. Pat. Law Assoc. Sel. Leg. Pap.* 1 (No. 2), 81 (1983).
8. *American Patent Law Association Plant Variety Protection Committee Annual Report* (1981).
9. 19 *U.S. Code*, sects. 1337 and 1337a.
10. 35 *U.S. Code*, sect. 271.
11. 7 *U.S. Code*, sect. 2541.
12. *In re Argoudelis*, 168 *U.S. Pat. Q.* 99 (Court of Customs and Patent Appeals).
13. 7 *U.S. Code*, sect. 2401(a).
14. 7 *U.S. Code*, sect. 2402.
15. 7 *U.S. Code*, sect. 2401(a)(1).
16. 7 *U.S. Code*, sect. 2401(a)(2).
17. *In re Waller* (U.S. Secretary of Agriculture decision, 14 July 1981).
18. 7 *U.S. Code*, sect. 2401(a)(3).
19. 7 *U.S. Code*, sect. 2544.
20. 7 *U.S. Code*, sect. 2543.
21. *Delta and Pine Land Co.* v. *Peoples Gin Co.*, 694 *Fed. Rep.* 2nd ser. (Fifth Circuit Court, 1983).
22. 28 *U.S. Code*, sect. 1498.
23. U.S. House of Representatives, *House Rep. No. 1129* (71st Congress, Second Session, 10 April 1930; U.S. Senate, *Senate Rep. No. 315* (71st Congress, Second Session, 3 April 1930).
24. *Graver Tank & Mfg. Co.* v. *Linde Air Products Co.*, 339 *U.S. Rep.* 605 (U.S. Supreme Court, 1950).
25. *Ex parte Jackson*, 217 *U.S. Pat. Q.* 204 (Patent and Trademark Office Board of Appeals, 1982).
26. *Regnum Veg.* 22, 30 (1961).

RESEARCH ARTICLE

A Deep 6-Centimeter Radio Source Survey

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Abstract. *The Very Large Array has been used to survey a small region of sky at a wavelength of 6 centimeters down to a completeness level of 60 microjanskys—about 100 times weaker than the faintest radio sources that have been detected with other instruments. The observed source count at flux densities below 100 millijanskys converges in a manner similar to the lower frequency counts, although there is some evidence for an excess of sources weaker than 100 microjanskys. The sources in the survey are preferentially identified with faint galaxies.*

The shortest wavelength at which extensive radio source surveys have been made is 6 cm. At this wavelength surveys by the National Radio Astronomy Observatory (NRAO) and Max-Planck-Institut (MPI) have covered most of the northern sky down to a limiting flux density of 600 millijanskys (mJy), while the various Parkes surveys provide complete samples of sources down to 1 Jy (*1*). Over limited regions of the sky other single-dish surveys made at NRAO and MPI are complete to 35 mJy (*2*), 20 mJy (*3*), 15 mJy (*4*), and 14 mJy (*5*). Synthesis surveys covering even smaller regions have reached levels of 4.5 mJy at Westerbork (*6*) and 0.5 mJy at the Very Large Array (VLA) (*7*). We have used the VLA to extend the surveys to sources that are as faint as 60 μJy at 6 cm, or about 100 times weaker than levels reached with other instruments at any wavelength. Source catalogs constructed from these surveys provide the basis for further studies in the radio region and in other parts of the spectrum. Further investigation is in progress on the nature of these weak radio sources, their spatial distribution and luminosity function, and how these properties change with cosmological epoch.

Counts of radio sources made at centimeter wavelengths are of particular interest since, for the stronger sources selected at this wavelength, flat-spectrum compact sources and steep-spectrum extended sources (which dominate the long-wavelength counts) are present in roughly equal numbers (*5*, *8–10*). Previous surveys made at 6 cm for relatively bright sources show that for $S > 100$ mJy (approximately the 20,000 brightest sources in the sky) the counts are closely represented by the "Euclidean" law

$$\eta_0(S) = 90\ S^{-2.5} \qquad (1)$$

where $\eta_0(S)$ is the number of sources with flux density S per unit flux density interval.

Between 10 and 100 mJy the 6-cm counts begin to decrease in a manner qualitatively similar to the long-wavelength counts of the steep-spectrum sources (*5*, *8*, *9*). However, the extended Euclidean plateau at 6 cm differs dramatically from the long-wavelength count, which is characterized by a steep rise for strong sources (the brightest 1000 or so) followed by a rapid decrease in the density of the weaker sources.

In this article we report on observations of very weak radio sources at 6 cm, and we discuss the angular size, spectra, and optical identification of these weak sources.

Observations and Reductions

In order to investigate the number density of very faint radio sources, we have mapped a small area of sky, using the VLA to detect all sources with a flux density greater than 60 μJy. These new observations include the weakest radio sources yet cataloged and reach a source density of 6×10^5 sources per steradian. Supplemental information concerning this sample of sources was obtained through (i) VLA observations at 20 cm to determine the spectral index of the sources and (ii) optical observations with the 4-m telescope at Kitt Peak National Observatory (KPNO) to aid in the identification of the sources.

The 6-cm observations were made in the D configuration of the VLA to synthesize a 700-m-diameter antenna on a field centered at right ascension (α) = $00^h15^m24^s$ and declination (δ) = 15°33′00″ (epoch 1950.0). The resolution is about 18 arc sec and no emission will be missing for sources less than 120 arc sec in size. The general area of the field

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was not selected at random but was chosen for the following reasons. In order to observe during the night with the available scheduled time in the D configuration, the right ascension of the field had to lie near 1^h. Several deep optical plates were available for the chosen field (selected area 68.1). A high-resolution x-ray map from the Einstein satellite covered most of the area near the field. Finally, observations at Westerbork at 20 cm showed that there were no bright sources near the field which would interfere with the VLA high-sensitivity radio survey (*11*). The specific location of the Deep Field was random within the area constrained by these criteria. These selection biases should not affect the statistics of the present survey.

The observing program was also designed to measure the fluctuations of the cosmic background radiation as well as the number density of weak sources. The results on the background fluctuations are given by Fomalont *et al.* (*12*). The observations consisted of four 12-hour periods on 27, 28, and 29 September and 2 October 1981 to give a total integration time of about 40 hours on one field. All observations were made at elevations greater than 14° above the horizon. The diameter of the field was limited by the primary beam size of the 25-m antennas: 8.9 arc min full width at half-maximum and 17.1 arc min full width to the first nulls. Both the phase tracking (fringe-stopping) and antenna pointing were located at the field center position. In addition, we observed ten other fields surrounding the Deep Field for about 40 minutes integration each in order to provide better statistics for the source count level above 350 μJy. We refer to these as the Intermediate Fields; the locations of the fields are given in Table 1.

Table 1. Field centers.

Field	Position (epoch 1950.0)	
	α	δ
I1	$00^h14^m25^s.84$	15°19′00″
I2	00 15 24.00	15 19 00
I3	00 13 27.63	15 33 00
I4	00 14 25.84	15 33 00
I5	00 16 22.16	15 33 00
I6	00 13 27.63	15 47 00
I7	00 14 25.84	15 47 00
I8	00 15 24.00	15 47 00
I9	00 14 25.84	16 01 00
I10	00 15 24.00	16 01 00
Deep	00 15 24.00	15 33 00

The observations were made at night to avoid interference from the sun in the sidelobes of the antennas. The system noise temperature was 60 K in both left- and right-circular polarization channels, each with a bandwidth of 50 MHz. The antenna pointing was accurate to 0.3 arc min and the delay was tracked to better than 1.5 nsec. All data in which one antenna shadowed another were excluded from the analysis. The instrumental and atmospheric gain and phase fluctuations were monitored by observing the nearby calibrator source 0007 + 171 for 2 minutes at 30-minute intervals. The assumed position for the calibrator is $\alpha = 00^h07^m59^s.383$, $\delta = 17°07'37''.50$ (epoch 1950.0). An observation of 3C48, with an assumed flux density of 5.36 Jy at 4.9 GHz, was used to determine the flux density scale of the observations. It should not be in error by more than 3 percent.

Radio maps were made by following standard Fourier inversion techniques and the clean algorithm was used to remove the effects of the sidelobes in the synthesized beam pattern. The data were mapped so that each 20-second sample of the visibility data at each baseline was given equal weight (so-called natural weighting) to produce the optimum signal-to-noise ratio for a point source. The area of the cleaned synthesized region was 25.6 arc min square (256 by 256 map with a pixel separation of 6 arc sec), which extends beyond the null of the primary beam pattern of the 25-m antennas. The resolution of the map was 18 arc sec. For each of the 4 days of observations radio maps of the field were made separately in the right- and left-circular polarizations. These maps were compared to judge the reliability and sensitivity of the observations. The total intensity map was made by averaging the eight maps (4 days times two polarizations).

The sensitivity parameters of the observations are given in Table 2. The detection level was 60 μJy for a point source. Over most of the field of view the root-mean-square (rms) noise was 11 μJy; however, the noise level increased up to 18 μJy within the inner 5 percent of the field. The increased noise near the field center was caused by low-level correlated signals between the antennas; details are given by Fomalont *et al.* (*12*). Seven percent of the data were edited in order to decrease the effect of these signals. For the Intermediate Fields the detection level of 350 μJy was about 4.5 times the rms noise level.

The 20-cm VLA observations were obtained in February 1983 in the C configuration, which nearly matched the resolution of the 6-cm observations. Seven hours were integrated on the Deep Field, and four other surrounding fields were each observed for 25 minutes in order to overlap all of the intermediate 6-cm fields. Table 2 also contains the sensitivity parameters for these observations. The data were used to obtain estimates of the flux density at 20 cm for the sources found in the 6-cm observations; hence no detection limit is applicable. These data were reduced and processed in a manner similar to the 6-cm data.

Optical observations with the prime focus RCA/CCD camera on the 4-m Mayall telescope at KPNO were made on two nights in November 1982. Eight CCD frames, each 3 by 5 arc min in area, were needed to cover all the sources in the Deep Field. No observations were

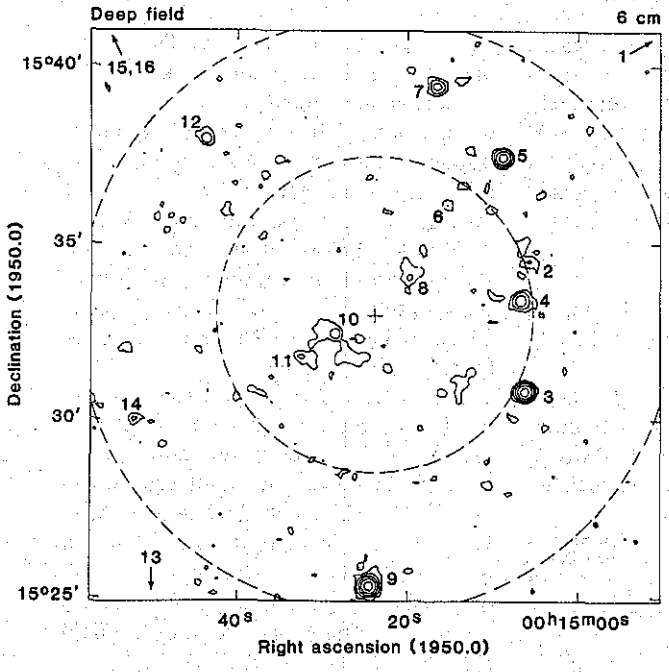

Fig. 1. Contour map of the Deep Field at 6 cm. Contour levels are at 25, 50, 100, 200, and 400 μJy per beam. Only sources with a second contour level have been included in Table 3 and are labeled with their catalog numbers. The cross shows the position of the field center and the two dashed circles show the 50 percent and 8 percent sensitivity loci of the primary beam. Sources 1, 13, 15, and 16 lie outside the 8 percent response. No correction for the primary beam response has been applied to the map.

prior art varieties, the question of how much difference or the type of difference cannot be looked into by PVPO. In other words, if there is any difference, plant variety protection must be granted. Although there is support in the seed industry for such a position, the time will come when PVPO and the courts will have to determine what constitutes a difference.

The Plant Patent Law. There are suggestions in the legislative history of the Plant Patent Law (*23*) that the importance of the distinction between the new variety and prior art varieties cannot be considered by the U.S. Patent and Trademark Office in its determination of whether a new plant is distinct. In other words, if there is any difference it is sufficient to meet the requirement of distinctiveness.

The General Patent Law. The general patent statute provides a situation different from that of the Plant Variety Protection Act since a variety, to be protectable under the general patent statute, will have to meet the additional requirement of unobviousness. The requirement of unobviousness inherently involves the question of how large a difference must exist for a variety to be unobvious in view of prior art varieties. It also differs from the Plant Patent Law in that it provides for multiple claims.

The requirement of difference between varieties for which protection is being applied and prior art varieties is being considered by UPOV under the concept of minimum distance between varieties. At a meeting sponsored by UPOV in Geneva, Switzerland, in November 1983, the question of minimum distance was discussed.

The breadth of protection provided by the patent or certificate is very important in an infringement suit. For example, the patent or certificate holder must show that the accused variety infringes the patent or certificate. One approach would be to have the breadth of protection tied to the ease of securing the protection. For example, if there is no requirement for minimum distance to obtain protection (which is the case under most registration systems) then there should be no doctrine of equivalents. The doctrine of equivalents is a principle of patent law that holds that a patent may be infringed even though the alleged infringing matter is not an exact duplicate of that claimed in the patent if it does the same thing in substantially the same way (*24*). This is a well-known principle in patent law, but it remains to be seen whether it will be applied in plant variety protection lawsuits or lawsuits under the general patent statute in which protection of plant varieties is sought.

In the case of *Ex parte Jackson* (*25*), it was held that even though three microorganism species of a genus were disclosed in the patent, 35 *U.S. Code*, section 112, was not met since the genus encompassed species other than those specifically exemplified. This raises the question of whether or not it would be possible to obtain generic coverage for similar plant varieties of a species under the general patent statute. Specifically, how many species will have to be disclosed to support the genus?

Plant Variety Denominations

No discussion of patent-like protection would be complete without mention of plant variety denominations (names). One requirement of protection under the plant breeders' rights laws of most countries and UPOV is that the variety for which protection is sought must be given a varietal name. The varietal name of a variety is similar to the generic name of a chemical compound. It is not a brand name or a trademark. The varietal name is important because it identifies the new variety by name and it establishes a name for the variety that is separate and distinct from any trademark that may be associated with the variety. In most countries it is not possible to register varietal names as trademarks because a variety could first be protected under plant variety protection laws and then protected perpetually under trademark laws.

Under the UPOV Convention the same varietal name cannot be given to varieties of the same species or a "closely related species." The latter phrase has elicited considerable debate between UPOV member states and has resulted in the drafting of guidelines on varietal denominations. It is probable that there will be continued discussion of the draft guidelines before a final version is adopted.

The Plant Variety Protection Act requires the assignment of a varietal name to the variety for which protection is being sought. However, there was no requirement in the Plant Patent Law until the United States joined UPOV. The Patent and Trademark Office established guidelines for varietal names for varieties claimed in plant patent applications. The guidelines are based on the International Code of Nomenclature (*26*).

Conclusion

Because more and more private research funds are being poured into the development of plant varieties, stable and definitive protection for these varieties and parts thereof is very important. It remains to be seen whether adequate protection is available within the framework of the existing patent statutes or whether new legislation will be required.

References and Notes

1. Frumkin, *J. Pat. Off. Soc.* **27**, 143 (1945).
2. International Convention for the Protection of New Varieties of Plants (2 December 1961; last amended 23 October 1978). There are 17 signatories to the treaty, including the United States, which became a member in 1980.
3. 35 *U.S. Code*, sect. 161 (patents for plants) (last amended 1952), states

   "Whoever invents or discovers and asexually reproduces any distinct and new variety of plant, including cultivated sports, mutants, hybrids, and newly found seedlings, other than a tuber propagated plant or a plant found in an uncultivated state, may obtain a patent therefor, subject to the conditions and requirements of title. (Amended September 3, 1954, 68 Stat. 1190.)

   The provisions of this title relating to patents for inventions shall apply to patents for plants, except as otherwise provided."
4. 7 *U.S. Code*, sect. 2321.
5. 35 *U.S. Code*, sect. 101 (inventions patentable), states

   "Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title."

   Section 102 (conditions for patentability; novelty and loss of right to patent) states

   "A person shall be entitled to a patent unless—

   (a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for patent, or

   (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of the application for patent in the United States, or

   (c) he has abandoned the invention, or

   (d) the invention was first patented or caused to be patented, or was the subject of an inventor's certificate, by the applicant or his legal representatives or assignees in a foreign country prior to the date of the application for patent in this country on an application for patent or inventor's certificate filed more than twelve months before the filing of the application in the United States, or

   (e) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent, or on an international application by another who has fulfilled the requirements of paragraphs (1), (2), and (4) of section 371(c) of this title before the invention thereof by the applicant for patent, or

   (f) he did not himself invent the subject matter sought to be patented, or

   (g) before the applicant's invention thereof the invention was made in this country by another who had not abandoned, suppressed, or concealed it. In determining priority of invention there shall be considered not only the respective dates of conception and reduction to practice of the invention, but also the reasonable diligence of one who was first to conceive and last to reduce to practice, from a time prior to conception by the other."

   Section 103 (conditions for patentability; nonobvious subject matter) states

   "A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter

patent does provide such protection. This view is not held universally, however, and some feel that legislation should be introduced to make it clear that plant parts are protected by plant patents and that their importation into the country would constitute infringement of the plant patent (*8*).

Other commentators suggest that protection against the importation of cut flowers obtained from a protected variety is available in the International Trade Commission (ITC) under section 1337(a) of the Tariff Act (*9*). This act affords a remedy against an importer who commits an unfair trade practice that injures an industry in the United States. The Tariff Act specifically provides that infringement of a patent can constitute an unfair trade practice. Section 1337(b) of the Act is applicable because under the General Tariff Act the infringing acts must fall within the infringement provisions of the U.S. patent laws (*10*). However, section 1337(b) makes it an infringement to utilize a patented U.S. process in a foreign country for the purpose of producing an article or a good that is introduced into the United States. Since a plant patent covers asexual reproduction of a plant, it is in the nature of a process patent. Therefore, it can be argued that proceedings under the Tariff Act should be based on section 1337(b). While the situation of cut flowers has been cited as an example, there is no reason that the same argument cannot be equally applied to other plant parts.

Unlike the patent laws, which define infringement generally in terms of sale, manufacture, and use, the Plant Variety Protection Act spells out what constitutes an infringement of a plant variety certificate (*11*). It is clear from 7 *U.S. Code*, section 2541(6), that the sale of plant parts that can be used for reproduction of the variety constitutes infringement.

Protection of plant parts per se (protection that is sought for the parts themselves without any protection for the whole plant) is questionable under the Plant Patent Law and the Plant Variety Protection Act since both statutes provide protection for plants. How, then, may plant parts be protected? There are parts of plants that are readily identifiable—for example, the visible parts such as fruits, leaves, stems, and roots. Then there are the more esoteric parts such as cells, segments of DNA, plasmids, genes, and combinations thereof.

Since neither of the specific plant variety protection laws clearly provides protection for all parts of plants, it would seem that protection could appropriately be sought under the general patent statute.

If the plant part itself can be used to reproduce a hybrid plant or as part of a process to produce another useful item, an alternative means of protecting the part would be by trade secret. Trade secret law, while not governed by federal legislation, is well defined and is governed by state law in the United States. The practice of protecting hybrid plants by controlling the release of their parental lines was the primary reason that hybrids were excluded from plant variety protection.

Living Versus Inanimate Matter

The basic policy behind any type of protection system for intellectual property law is the granting of an exclusive right to the inventor for a clear description of the subject matter so that it can be useful to the public when it is disclosed. In other words, the individual is rewarded for disclosing new information that can be put into the general pool of knowledge and used to advance technology and benefit mankind. It is on the question of adequate disclosure that much controversy has arisen regarding patent-like protection for technical products in general and plant variety and their parts specifically. To help ensure that this general public policy of disclosure is carried out, the general patent statute has very stringent requirements for the content of the patent application. These requirements are set forth in 35 *U.S. Code*, section 112, which reads in part as follows:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention.

This section states in essence that the specification shall contain a written description that clearly defines the invention in terms that can be followed by one having ordinary skill in the art. It requires that the invention be reproducible, that is, when one skilled in the art follows the description contained in the application, the results obtained by the patentee can be duplicated. A person having ordinary skill in the art is a person who understands and is knowledgeable about prior inventions in the field to which the invention relates.

Because plant materials can change form without intervention by man, questions have been raised as to the ability of the inventor to describe an invention in such a manner that it can be duplicated by those skilled in the art. Specifically, the concern is that even though techniques are followed as set forth, changes or slight variations may cause changes in results.

Discussed below are ways in which these concerns for adequacy of description and reproducibility have been addressed.

The Plant Patent Law. In the legislative hearings preceding passage of the Plant Patent Law the questions of description and reproducibility were approached in two ways. Plant patent applications would not have to meet the stringent requirements of 35 *U.S. Code*, section 112. Specifically, 35 *U.S. Code*, section 162, expressly states that plant patent applications are exempt from the requirements of 35 *U.S. Code*, section 112, and that all the breeder has to do is describe the plants to the best of his ability. Another aspect that has more to do with reproducibility than description is the requirement for asexual reproduction. When the Townsend-Purnell Act was being considered, it was felt that plants could not be reproduced true to form by seed and that the only way to do this was by some form of asexual reproduction. Thus, the limitation.

The General Patent Law. Questions about reproducibility increased during the growth of the fermentation industry. The fermentation industry has been important in the development of antibiotic and steroid technology. The intensity of the questions heightened when attempts were made to claim specific organisms. These organisms were important in producing various antibiotics. One of the important requirements of 35 *U.S. Code*, section 112, is that the patent application contain a description that is complete at the time of filing. That is, one skilled in the art should be able to pick up the application as it is filed and reproduce the invention. In the case *In re Argoudelis* (*12*) it was established that this disclosure requirement could be satisfied by indicating that the microorganism claimed or used in a claimed process has been deposited at a depository and that it would be made available upon the issuance of the patent. This method of meeting the disclosure requirements has been accepted by most of the patent systems throughout the world.

With respect to the protection of plant varieties under the general patent stat-

from our experience is in the area of the design of chips. Chips are made by creating masks for the lithographic process, which are essentially pictures of various layers in the silicon. They are tremendously complex, as there can be more than 100,000 transistors on a single chip. The data that go into each mask are stored in a computer, and this common database is accessed by the large number of engineers, who contribute individually to forming the mask. This kind of sharing is a commonplace of engineering today and is true of other aspects of chip design.

In software, collaboration of this sort is also routine. A compiler development involved the sharing of work between a California laboratory, the Yorktown laboratory, and an outside software company, with versions of the program transmitted back and forth continually between the three locations through the network. Various versions of a program under development are centrally stored, and the computer scientists working on it have access to it to update the individual versions and make changes. Software development today is often dependent on this kind of sharing.

Management

In the industrial research community there is a third class of people associated with scientific activity, and that is management. These are the people, mostly scientists and engineers themselves, who are responsible for the execution and coordination of the large variety of projects. For management in general, not only scientific management, the emphasis is not on MIPS or displays but on sharing.

In order to keep up with what is going on in a large research laboratory, mail systems, both text and audio, are extremely useful. One advantage is that they desynchronize communication. When you have an idea or want to know something, you can send your message off and it does not matter whether the people you send it to are there. When they come in or are available, they can find your message and reflect on it and reply. Another advantage is that of addressing a large number of recipients simultaneously. After registering your message only once, you can send it to any of those on a given list of people. These tools are very important to us already, and we expect that they will become widely used and will be major communication tools for management.

Discussion

To summarize, among the three populations that we have had experience with, for scientists MIPS come first; for engineers MIPS, displays, and sharing all play a role; and for management, communications is clearly more important. Are these patterns indicative of fundamental cultural differences, or simply transient reactions to a rapidly changing environment?

All aspects of computer technology will continue to evolve at a rapid pace. Figure 15 shows schematically our view of the computing system of the future. It is a complex of powerful engines connected in a network by good communications facilities. There is a central data-processing (DP) complex in which the 100-MIPS machines described earlier are located; hooked up to them are specialized processors, designed especially for engineering and scientific use. Scattered around are smaller processors, to which intelligent processors based on single microprocessor chips with a power of perhaps 10 MIPS are attached. Local area networks are hooked through a gateway and through communications to other systems, including the large one. Intelligent workstations (IWS) are connected to the network through a private branch exchange (PBX) and also to a number of intermediate machines that play a role as departmental processors or communicate directly with each other through a peer-coupled system. In addition, the network will transmit not only printed messages but also images and voices. Everything we know how to do today will still be done, but with a factor of 10 improvement in power. In addition, there are some things that are possible, though harder to predict, such as symbolic rather than numeric calculation and novel logic-based types of software such as expert systems. These requirements may lead to machines specialized for these needs.

More MIPS will mean, as in the solid-state example, that more problems become tractable. More displays, higher resolutions, and greater interactivity will mean that novel ways of using the displays, such as three-dimensional and other more complex techniques, will become more significant. Increased sharing should lead to better management and the use of project-sharing techniques worldwide.

These are the simple straight-line projections for the evolution of the technology. Its impact on various research activities is in the much more difficult realm of qualitative projections.

Will another factor of 10 cause scientists to cooperate and communicate through computer networks as engineers already do? It may be that engineers and

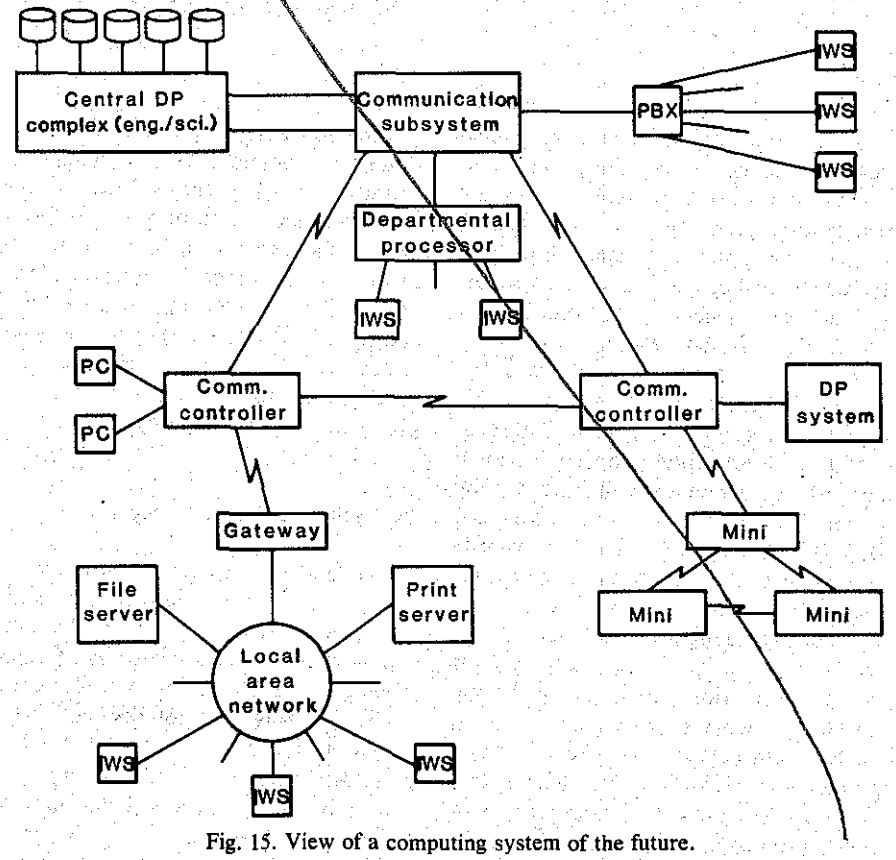

Fig. 15. View of a computing system of the future.

53. Lung disease patients with negative DTHR-T had: caseating granuloma (1), silicosis (3), tuberculosis with pleural effusion (1), intravascular angiogenic tumor (1), chronic bronchiectasis (5), chronic organizing interstitial pneumonitis (4), recurrent cyst (1), coccidioidomycosis (1), sarcoidosis (2), chronic obstructive pulmonary disease (8), chronic asthma emphysema, and pneumonitis (5), pneumonia (3).
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National R & D Policy: An Industrial Perspective

Roland W. Schmitt

Industrial policy has become one of the hot issues on our national agenda, with various advocates telling us how to beat the Japanese and solve the problems of unemployment, inflation, and industrial stagnation. The 1984 presidential candidates are picking up these ideas and testing them.

Industrial policy has many components—fiscal, monetary, and regulatory, for example. It touches on many areas, from international trade to retraining the work force. I can bring my expertise to only one corner of this many-sided subject: research and development policy. To me, industrial policy means what the government must do to shape our national industrial posture, and a clear understanding of what government should not do.

There has been no lack of proposals. Bills put before Congress in recent years have called for such changes as the establishment of a National Technology Foundation, or a Cabinet-level Department of Trade and Industry; the selection of a National Commission on Technological Innovation and Industrial Modernization to tell us "what the economic, educational, and industrial priorities of the United States ought to be"; a Presidential Program for the Advancement of Science and Technology; and a Commission on High Technology and Employment Potential. Another proposal would establish a government program to conduct research and development on improved manufacturing techniques; others would exempt joint research and development efforts from the antitrust laws.

All these proposals to aid U.S. R & D show a healthy and encouraging concern about the state of American industrial technology, but they may at the same time distract politicians and policy-makers from the most important need and the most important step that government can take to strengthen U.S. innovation. That task is to ensure and strengthen the health of our university system—in both the performance of basic research and the training of research manpower. The distraction is especially great if Washington pays too much attention to the growing number of calls for the government to take over the job of selecting and supporting R & D programs aimed at commercial results.

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The Federal Role

In the commercial R & D area there are some things that government must and can do, and other things it cannot and should not do. Government has a crucial role to play in creating favorable conditions for commercial innovation, but not in actually producing those innovations. There are several reasons for this.

First, successful innovation requires a close and intimate coupling between the developers of a technology and the businesses that will bring products based on that technology to market and are themselves in touch with that market. This is essential in a diversified company, and even more essential in a complex and diversified economy. The R & D people must comprehend the strategies of the business as well as know what the market constraints are and what the competition is up to. The business people, in turn, must understand the capabilities and limitations of the technology. They must possess the technical strength to complete the development and believe strongly enough in the technology's potential to make the big investment needed to bring it to market.

Second, innovation works best if this close coupling is in place during the entire innovation process. It should exist when the R & D project is identified and should continue through planning and development. It must survive the inevitable adjustments during development, caused by shifting market constraints and technical surprises. It must withstand the decision points—when to go ahead or when to quit.

Finally, in a free-enterprise system, governments not only do not create the markets for products but are notoriously slow in reacting to shifts in the marketplace. They lack the crucial entrepreneurial spirit to perceive or acknowledge opportunities early in their development.

During the years of heavy government involvement in energy R & D, we used to hear over and over again the expressions "technology transfer," and "commercialization." Those terms embodied the notion that once a technology was developed by a government contractor or a national laboratory, the technology could then somehow be transferred to the marketplace and commercialized.

That did not happen for a simple reason. Technology transfer is not a separate process occurring downstream from R & D. The user and the performer of targeted R & D need to have established a close relation before there is anything to transfer.

In energy R & D, there were some who fell into the trap of thinking that if they got a concept defined, the technology to work, and someone to produce a favorable economic analysis, then commercialization would follow. They forgot to find out whether the customers would buy the product. The result was a misdirection of effort and money into technologies that never had a chance of commercial success.

Even in agriculture, where the United States has a great history of innovation, underlying research on corn genetics was performed at university research stations and largely supported by government. But private seed companies converted that research into hybrid corn products.

A close relation between the user and the performer of R & D cannot, in general, form when government selects commercial R & D targets. Instead, the government ends up being a third party—one that knows a great deal less about the technology than the developer and a great deal less about the market than the user.

As an example, there are proposals that the government fund R & D in manufacturing technology, in such application areas as programmable automation, robotics, advanced sensors, and computer-aided design and manufacturing. Part of this funding is to support R & D work to be done by industry.

These are key technologies for the future but, because they are so important, a large and growing number of companies are already addressing them. General Electric is investing millions of dollars in each of them. And, in each one, we are faced with a large number of tough competitors—foreign firms and U.S. firms, established firms and new ventures, joint ventures and industry-university cooperative programs. In just one corner of computer-aided design, for example, the field of solid modeling, we are competing against at least a dozen capable firms—established giants, smaller rivals, and newer ventures.

It is simply not plausible for an administrator in Washington—even with the help of a blue-ribbon advisory panel—to pick the winning solid-modeling product better than the dozen firms slugging it out in the marketplace. And even if government could pick the winner, that is only the first step. The suppliers of the funds, the performers of the R & D, and the businessmen who deal with the customers have to tie themselves together in a long-term relation. A government funding agency cannot create that kind of relationship.

There is, however, one important exception. It occurs when the government is the customer for innovation—as in defense R & D. Government should concentrate its development efforts on these needs of its own. If history is any guide, it will thereby also generate products and technology that can be tapped for commercial uses.

The government has clear needs in the area of supercomputers for weapons research, cryptanalysis, weather forecasting, economic modeling, the design of improved airfoils and projectiles, and many other uses. By meeting its needs in supercomputers, the government will also be sponsoring the development of a product that has many valuable civilian uses, such as improved oil exploration, better understanding of crack formation and propagation in alloys, new techniques in computer-aided engineering, and the design of new materials based on theoretical principles. The supercomputer is a prime example of a technology in which the government should take the lead.

In very large scale integrated circuits (VLSI) the government will also be a major customer and thus has a major role in sponsoring development work. One emerging opportunity is in the area of inference chips—VLSI implementations of intelligent electronic systems that work in real time, based on custom chips rather than computers. These inference chips could be used in military systems, for example, to help the pilot of an F-18 with an engine hit by shrapnel make the best use of the 3.6 seconds he has in which to decide whether he can limp home or should bail out.

Inference chips will also have great value in many commercial uses, such as in creating three-dimensional computer-aided design images in real time and in helping smart robots plan their paths. Again, by meeting its own development needs, the government may advance technology that can be used in commercial innovations. When the government is not the customer, government selection of developments is unlikely to promote such innovation and economic growth.

Summary. An analysis of how the government can and cannot use research and development policy to improve the nation's industrial posture suggests four guidelines for federal R & D policy: (i) concentrate direct support on academically based research, not on government-targeted industrial R & D; (ii) concentrate on sunrise science and technology, not on sunrise industries and products; (iii) concentrate on strengthening the climate for privately based innovation, not on government-selected innovation; (iv) concentrate on development for the government's own needs, not on development for market needs.

Competition from Japan

At this point, I would expect some people to be thinking about the Japanese. Did their government bureaucracy not pick the commercial technical winners and put money behind them? No, it did not. At the heart of that question is a misunderstanding about the Japanese government's Ministry of International Trade and Industry (MITI). The popular picture depicts MITI as selecting target industries, picking out the technological developments they need, establishing a consortium of Japanese firms, and supporting the commercial R & D needed

perspective, the Department of Energy's program expense for just one unproved, highly speculative energy technique, magnetically contained fusion, was $295 million in 1982 alone. We face the same problem in several other crucial areas of university research. This is particularly true of engineering research—fundamental research in such areas as software engineering, automation, machining systems, materials engineering, and computer-aided engineering techniques.

The crucial distinction again is between support of the underlying research (the job that the government should be doing) and support of efforts aimed directly at generating products (the job the government should stay away from). Some of the bills before Congress do not clearly make this distinction. Consider, for example, the calls for government support of R & D in manufacturing technology. If a program for conducting the underlying research at universities is to be established, I will support it wholeheartedly. But when programs to produce more efficient manufacturing technologies are proposed, I worry that someone has ignored the difference between broadly relevant research and the job of selecting specific technology targets for new products and processes. And when anyone proposes conducting research utilization activities to encourage widespread adoption of these technologies, then I have serious reservations.

In the technology of controls, for example, fundamental theoretical advances are needed to catch up with the speed and power of microelectronics. Such work should be strongly supported at universities. But the job of putting research to work in, say, robots or machine tool controls for commercial markets should be addressed by private companies.

Some may be concerned that with so much emphasis on support of academic research in fast-moving areas, such as microelectronics and computer science, the needs of core industries, such as automobiles and steel, will be neglected. That is not so. The increases in efficiency needed by these industries will be provided much more by some of these fast-moving areas than by advances in the core technologies. These industries, too, are dependent on strong university research in the fast-moving areas. Moreover, these industries suffer from a lack of investment in already available technology. Giving them new technology without the corresponding investment to use that technology is hardly likely to improve their plight.

Immigration Policy

Another policy issue that strikes at the heart of our universities, yet is rarely discussed in the context of R & D policy, is immigration policy. In 1982 as many foreign students received engineering Ph.D.'s in our universities as did American students. Some regard these foreign students as a problem, and there even have been proposals to reduce their numbers. But the real problem is that not enough Americans are entering doctoral programs. The solution is to encourage more of our students, through adequately supported graduate fellowships, to go on to graduate studies. What is clearly not a solution is to force foreign students to leave. They are an important resource for our country. They account for a disproportionately large portion of our skilled manpower in the fast-moving areas of science and technology. They are not taking jobs away from Americans. They are filling a void and advancing U.S. science and technology. Historically the United States has benefited immeasurably from opening our doors to immigrant scientists and engineers. I need only mention such greats as Steinmetz, Alexanderson, and Giaever at General Electric; Tesla, Zworykin, and Ipatieff at other companies; and Fermi, Debye, Mark, and many others at American universities. Yet current laws create obstacles for foreign scientists who seek employment here. If we are truly concerned about enhancing U.S. industry's capability to do R & D, we should ease the regulatory barriers to hiring foreign-born students, especially those trained in this country. Proposed amendments to the Simpson-Mazzoli immigration bill now before Congress would do exactly that. Unfortunately, for reasons that have nothing at all to do with science and technology, that bill is now stalled in the House. The critical role that foreign scientists play in the United States must be addressed directly, rather than as an afterthought to a bill intended to deal with the problem of illegal, and largely unskilled, aliens.

Technology Leaks

A related national issue also directly affects the health of our universities: the problem of leakage of technology to the Soviet Union. In an attempt to stop that leakage, the Department of Defense and the Department of Commerce proposed regulations that would prevent foreign nationals from taking part in advanced microelectronics research in universities and industry. This is intended as just a first step. In the long run, the two departments are proposing to impose the same restrictions on virtually all fast-moving areas of advanced technology considered to be militarily critical.

There is no question that we must do a better job of preventing the Soviets from acquiring our technology, but such regulations are overkill. The Defense and Commerce Departments propose to change the export control regulations in ways that would seriously disrupt the nature of scientific discourse in U.S. universities and industrial R & D laboratories. No doubt some technology does leak to the Soviets in the course of our open scientific discourse. But by the Administration's own account, this is a very small part of the problem. It is counterproductive to impose such major restrictions on U.S. science and technology for such a small part of the problem. Again, foreign scientists play a critical role in most of our important areas of science and technology. Deny them access to these areas of research and we will do far more to damage our technological capabilities than any of the proposals being made in the name of industrial policy will do to help.

Conclusion

National R & D policy today poses both risks and opportunities. The excitement and attention that proposals for industrial R & D policy have generated threaten to distract us from the federal government's most important tasks. We need to go back to the basics. We need to remind ourselves of what it is that the government can and cannot do, and what it is that industry can and cannot do.

In summary, I want to suggest four specific guidelines for federal R & D policy: (i) concentrate direct support on academically based research, not on government-targeted industrial R & D; (ii) concentrate on sunrise science and technology, not on sunrise industries and products; (iii) concentrate on strengthening the climate for privately based innovation, not on government-selected innovation; (iv) concentrate on development for the government's own needs, not on development for market needs. I believe that these simple guidelines—many of which we have followed with success in the past, some of which we have violated with pain—will go a long way toward greatly strengthening and rejuvenating the dynamic innovative powers of our American system of research and development.