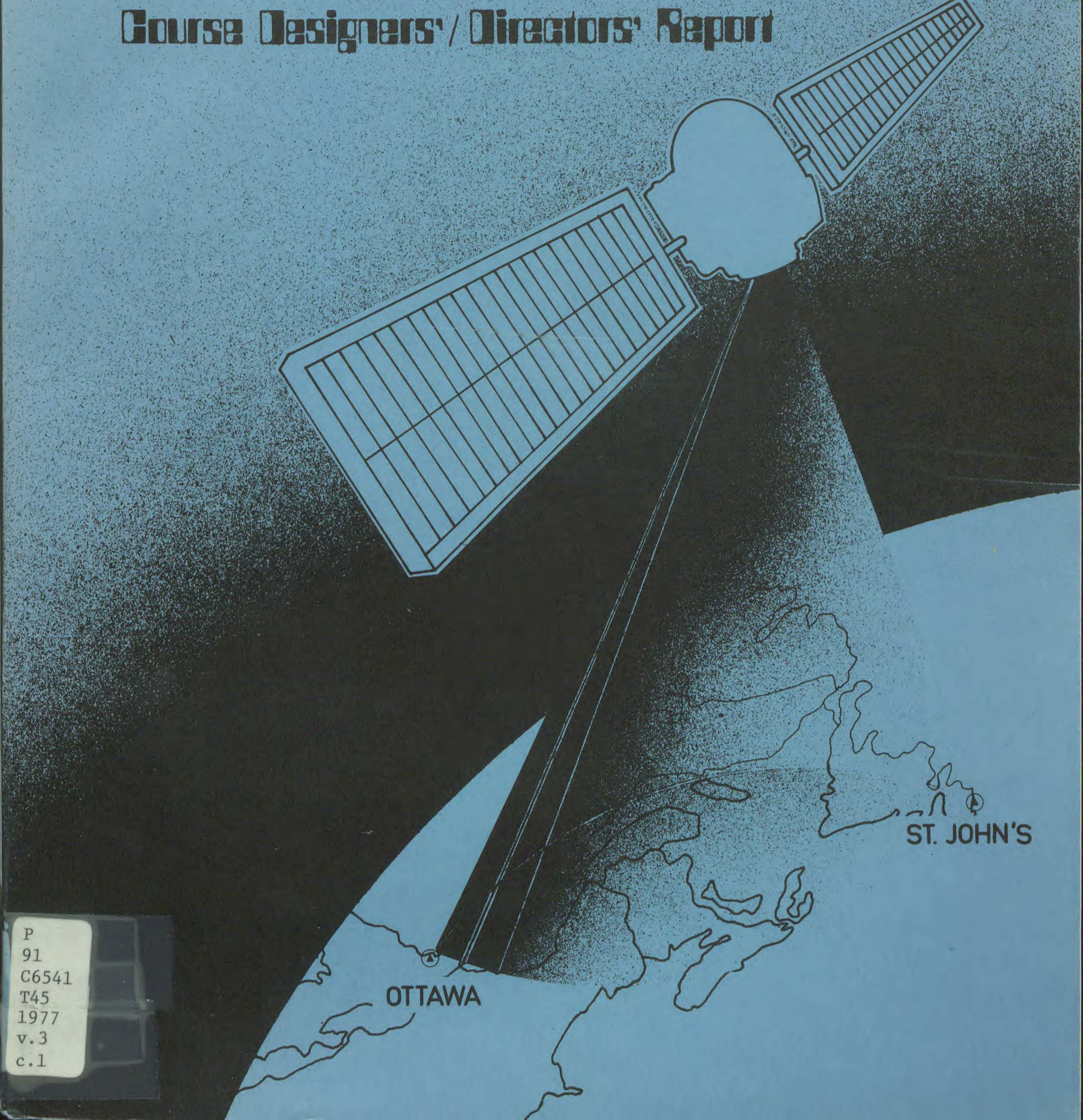
Tele-Training for Personnel Development

Course Designers' / Directors' Report



TELE-TRAINING FOR PERSONNEL DEVELOPMENT:

Course Directors'/Designers' Report

by

Glenn Barker

Terry McCoy

PUBLIC SERVICE COMMISSION OF CANADA

The Tele-Training for Personnel Development series is edited and published by the Satellite Project Office of the Secretariat Services Branch, Public Service Commission.

The purpose of this series is to document and disseminate information about the design, implementation and results of the Public Service Commission's Communications Technology Satellite (CTS) Project: Staff Training by Satellite. The Communications Technology Satellite was made available for pilot experimental periods by the Canadian Department of Communications.

Michael G. Ryan, Ph.D.

Series Editor

Reports in this series are entitled:

Tele-Training for Personnel Development: Staff Training by Satellite

Téléformation pour le perfectionnement du personnel: Modèle théorique

Tele-Training for Personnel Development: Course Designers'/Directors' Report

Tele-Training for Personnel Development: Evaluators' Report

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* Special acknowledgement goes to Dr. George J. Jull of the Communications Research Center whose early work on interpersonal telecommunications served as the foundation for much of the work in this project.

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FOREWORD

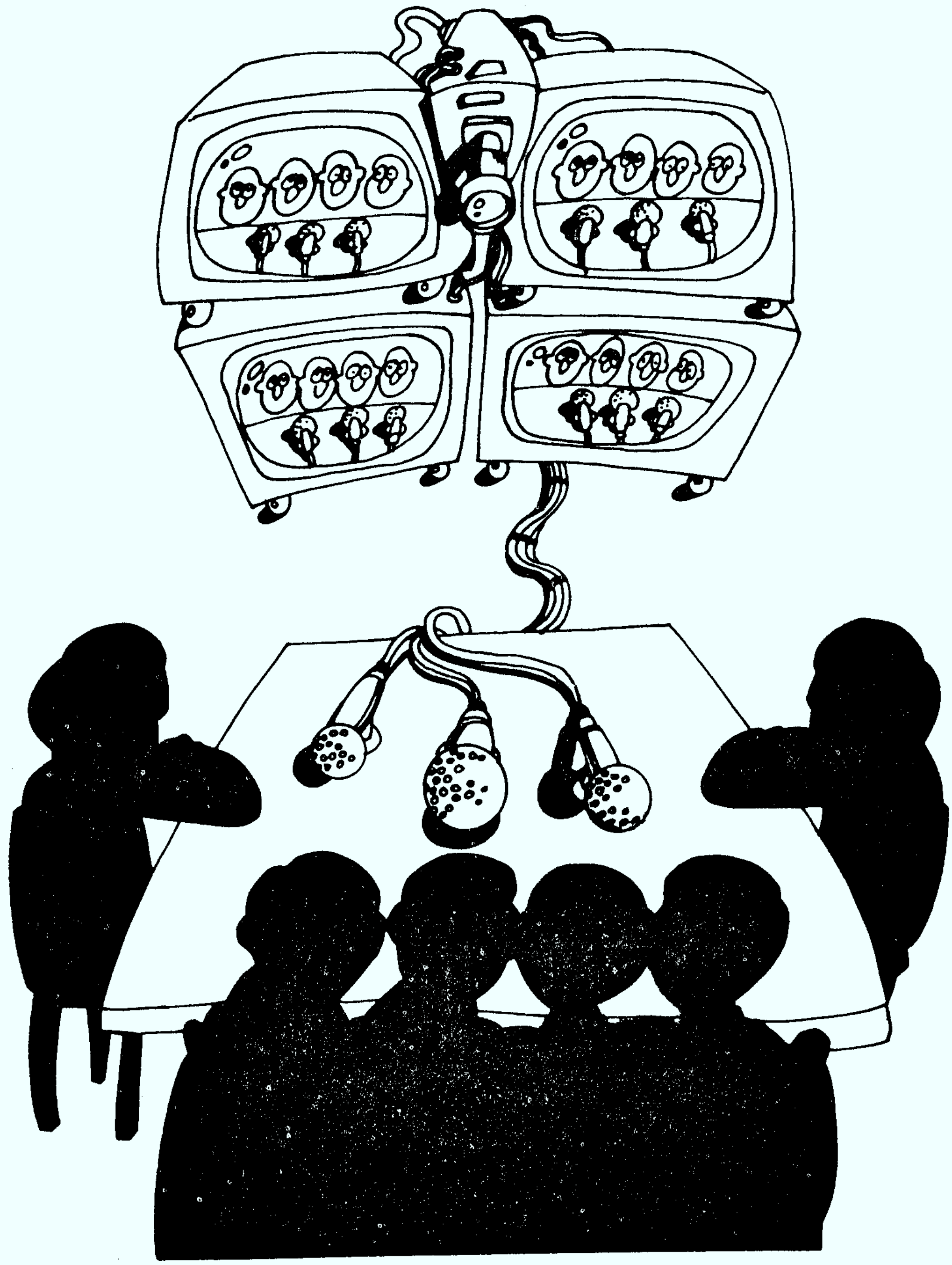
Tele-training for Personnel Development: Course Directors'/Designers' Report discusses the educational dimensions of the Staff Training by Satellite Project. This volume includes two summary articles on student directed learning and teaching by interactive television. These articles treat the course objectives, instructional aids, learning activities, and schedules as well as reporting on the experience of the course directors and specialists.

These articles are supplemented by a report describing the experiences of the course directors' during the laboratory simulation of the course. A second appendix provides a sample of the long-range planning process in operation. This long-range plan was completed by a Newfoundland based participant in the satellite mediated course using the methodology described in the course text book Foreward Planning in Government (Addendum 1). Supplementary readings may be found in Addendum 2.

To date the course has been give successfully on four occasions.

STAFF TRAINING BY SATELLITE

AN EXPERIMENT IN STUDENT-DIRECTED LEARNING



Glenn Barker and Terry McCoy

Introduction

An earlier report titled, "A Simulation of Staff Training By Satellite", February, 1977, * contained a description of a pilot course conducted in preparation for the experiment described within this report. The pilot involved 16 public servants in a student-directed course dealing with long-range planning. The participants were divided into four groups of four, with each group working in a separate room and communicating with the other groups via interactive closed-circuit television.

The Satellite Experiment

Having tested many crucial elements during the pilot course, the Public Service Commission began its experiments using the Communication Technology Satellite, on April 26, 1977. From this date, satellite transmissions took place for two hours every Tuesday and Thursday for the next eight weeks. During these 32 hours of satellite time, 40 federal and provincial public service managers and university administrators took part in one of two experimental courses. In each course, 16 of the participants were divided equally among four locations in St. John's, Newfoundland while four participants were in a single Ottawa location.

The design of the experiment also provided for a control group of 20 participants who constituted a single class and who received their instruction in Ottawa. The participants in the control group found themselves in a conventional classroom setting. They dealt with the same subject matter, used the same student-directed methodology and met with the same course directors as in the two satellite experiments.

* See appendix A

TABLE 1

SATELLITE EXPERIMENT TIME-TABLE

January 1977	April-May 1977	May - June 1977	
PILOT COURSE	SATELLITE COURSE	SATELLITE COURSE	CONTROL GROUP
• 4 locations • closed circuit TV • 16 hrs over 3½ days • 16 federal public servants	• 4 locations in St. John's • 1 location in Ottawa • TV satellite link • 16 hrs over 4 weeks • 20 federal public servants	• 4 locations in St. John's • 1 location in Ottawa • TV satellite link • 16 hrs over 4 weeks • 11 federal public servants • 6 provincial public servants • 3 university administrators	• 1 location in Ottawa • face-to-face • 16 hrs over 4 weeks • 20 federal public servants

This report contains the course designers'/directors' observations concerning student-directed learning and its application to audio-visual teleconferencing.

Methodology

Student-directed learning is based upon the premise that groups of learners will take the responsibility of determining the subject-matter to be studied, the learning activities to be engaged in and the resources to be used. A second essential aspect of this premise is that individuals or small groups within the larger one will be prepared to share what they have learned with the other members of the group. The course director in this situation is no longer primarily a dispenser of information or an initiator of all learning activities. He must act as a facilitator. That is, he does what is required to enable the students to carry out their own learning activities and achieve their own goals. Since, by its very nature, teaching by satellite involves groups separated from one another and from the course director, self-directed learning would appear to be ideally suited to the demands of the medium.

The Learner's Role

Self-directed learning assumes that the learner adopts or performs a certain set of roles, one set concerned with achieving the group's goals and the other with contributing to the group's morale.

The first set of roles, were identified by Benne and Sheats [1] as initiator-contributor, information-seeker, information-giver and opinion-giver. Other task functions of the learner included, elaborator, coordinator, orienter, evaluator-critic, energizer, procedural technician and recorder.

Benne and Sheats list morale or consideration functions, in their second set of roles. They itemized this second set as encourager, harmonizer, compromiser, gate-keeper and expediter, standard setter, group-observer and follower.

The Course Director's Role

With a student-directed methodology, a desirable leadership style is one which can be characterized as democratic, non-directive and group-centred. According to Brilhart[2] leadership style assumes that the course director's role is to perform the functions of guiding, stimulating thinking, facilitating communication and promoting co-operative interpersonal relations.

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1. Benne, Kenneth D. and Paul Sheats, "Functional Roles of Group Members" in Small Group Communication: A Reader, R. S. Cathcart, and L. A. Smovar, eds., W. C. Brown Co., Dubuque, Iowa, p. 135-136.

2. Brilhart, John K., Effective Group Discussion, W. C. Brown, Dubuque, Iowa, 1974, p. 136, 143.

The role of the course director also includes developing the group and its members, establishing the group's needs, discovering and facilitating the achievement of the group's goals or objectives.

The essential elements of this particular approach to training are presented in figure 1. The learner's role places him at the focal point. All other elements are related to one another and to the learner as a result of interaction and group decision-making. In a conventional learning situation the interaction and decision-making would be determined primarily by the course director.

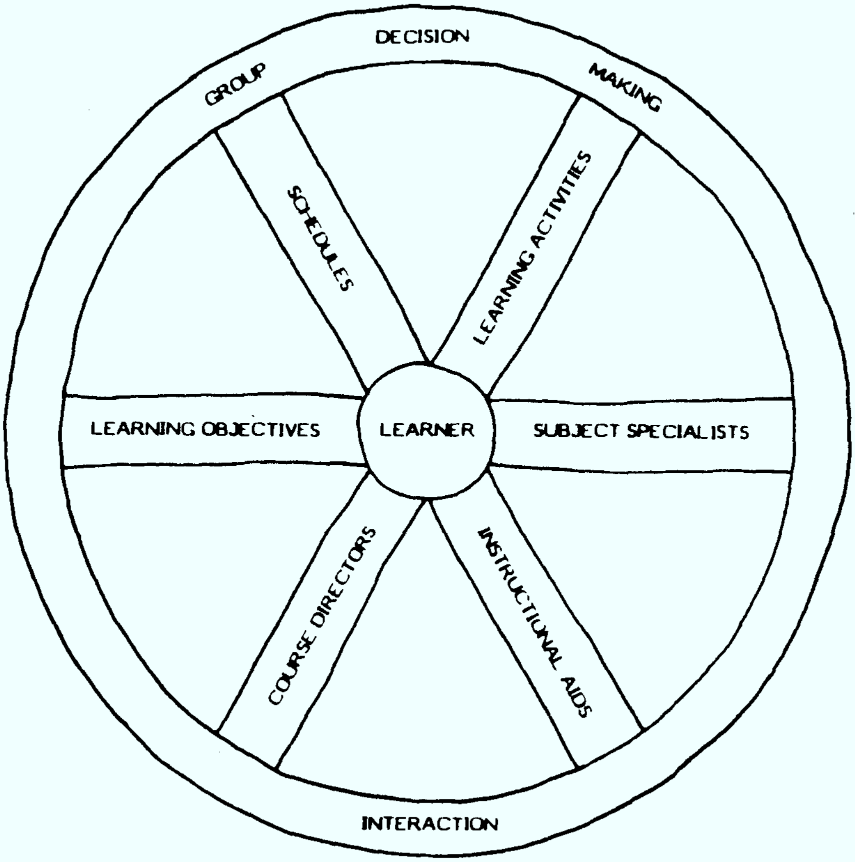

Figure 1
Elements of a student-directed training program.

Learning Objectives

In the case of the satellite experiment the participants themselves determined the course topic in their responses to an open-ended questionnaire, their choice being long-range planning. Follow-up questionnaires provided the course designers with a list of more detailed course objectives. In addition, at face-to-face meetings with all the participants,the course directors attempted to explain the participants' role and to encourage them to articulate their expectations and objectives. While the course designers expected a more enthusiastic response, only about 25% of the participants availed themselves of these opportunities to make an early input into the design and development of the course. It was only during the course that the participants and the course directors fully appreciated the fact that without a fairly in-depth understanding of the subject matter, it is exceedingly difficult to set out specific learning objectives.

At the beginning of each of the three courses, the participants once again had an opportunity to propose learning objectives. Because of either the novelty of the medium, the participants' lack of experience in long-range planning, or a combination of the two, the satellite groups offered little additional information. This was not the case with the control group where there was no problem with the medium and where a number of the members of the group had considerable experience in planning. Discussion became so animated that this group had difficulty in reaching consensus. The result was a disproportionate amount of class time being devoted to the refinement of their objectives.

Schedules

The first point at which the participants in the satellite course provided input into the schedule was two months prior to the course. At that time they made a recommendation to reduce the duration of the course by half. Almost all of them felt they could not free themselves from work for the proposed 16 sessions spread over a period of eight weeks. The outcome of this objection was a decision to recruit a second group of participants and run two four-week courses consisting of two-hour sessions every Tuesday and Thursday.

The second major scheduling factor was the one and a half hour time difference between St. John's Newfoundland and Ottawa. The fact that the course was held between 1:00 p.m. and 3:00 p.m., Ottawa time, meant that in St. John's it would run from 2:30 p.m. to 4:30 p.m. It was for the out-of-class group-work that these times had the most important implications. The Ottawa group worked on their off-camera assignments after 3:00 p.m., whereas the Newfoundland groups would come in to work on their assignments an hour or so before the Satellite link-up.

In order to eliminate some of the confusion that might arise over references to the different local times, and to maintain an awareness of the later hour in Newfoundland, the course room in Ottawa was equipped with two clocks, one on Ottawa time and one on St. John's time. Ideally, each location should have had this facility.

There was a minor problem that arose as a result of the hour at which the class started. The Newfoundland groups were on camera during that period when most of them would be accustomed to taking a break while in Ottawa, the session finished in time for their usual break. It was a desire to make the best use of the two hours of satellite time that prompted a decision to leave it up to the individual to decide whether he or she wished to take a break.

Although the schedule was dictated by available satellite time rather than by the intention to create the most favourable learning conditions, it turned out that there were some benefits to holding sessions for two hours a day every Tuesday and Thursday over a four-week period. The participants had a greater opportunity to do library research and to read related material between sessions than they would have had in one intense three-day course. They also had more time to prepare presentations they were to make to the other participants. The course directors benefited from having enough time to locate material corresponding to the direction the course was taking. Because the course extended over four weeks both the participants and the course directors were allowed time to enlist the contributions of subject specialists.

While it was easier for some participants to attend due to the fact that they were away from work for only two afternoons a week, this same schedule resulted in others missing a number of sessions. These absences occurred as a result of unforeseen events arising just prior to class time and requiring immediate attention. Participants who were prevented from attending sessions because of such situations expressed a preference for a three-day continuous course. An additional benefit of the continuous course would be that participants could plan to leave all their day-to-day work at the office and concentrate solely on the learning activity rather than having to carry their regular work load while following a course spread out over four weeks.

Learning Activities

There were three general types of learning activities engaged in during the course. They consisted of presentations made by participants, presentations by resource people and private study outside of class.

For the presentations made by participants, the course designers had prepared a long-range planning text, Forward Planning In Government;* a book of readings; Forward Planning: Selected Readings * and a classroom set of 60 articles, papers and reports. Participants were also given a set of suggested procedures for preparing and carrying out their presentations. These resource materials stemmed directly from the precourse survey of participant needs and from the experience acquired during the pilot study. The participants worked in small groups outside of class time to prepare their presentations. Although they initially expressed some doubt regarding their ability to act as instructors, they seemed surprised to discover the extent of knowledge they

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* Copies are included in separate volumes as Addendum 1 and Addendum 2.

already had and the degree of success they were capable of achieving. The general procedure for each group presentation was to analyze the topic, evaluate the main concepts, and to develop examples. The group also attempted to relate the topic under consideration to what had preceded and to prepare the way for what was to follow. Approximately 75 percent of the course was occupied by participant presentations and the discussions that resulted from them.

The rest of the course time was devoted to material presented by subject specialists. The subject specialist typically began with a short talk followed by a question period. In one instance where the guest speaker was unable to attend a session in person, a video tape was made of his talk and shown during one of the classes.

One of the resource people conducted a classroom exercise which required the participants to complete and classify certain lists of data prior to the exercise. The instructions for this compilation and classification task were given by one of the course directors for the participants to complete outside of the regular class time.

In the initial design of the experiment,16 hours of out-of-class time was allowed for the participants to work on their own or in small groups. Participants indicated that the groups appeared to make the best use of this time when they were working on an actual class presentation. The televised discussions demonstrated that a number of participants were conversant with a variety of the readings that were provided at each location. It would be difficult however to estimate the actual amount of private study that the participants managed to accomplish.

Subject Specialists

In line with the methodology which held that the participants should not only identify their own learning objectives, but also the means of achieving them, the experimental model assumed that the participants would invite or suggest subject specialists to act as in-class resource people. The first request for suggestions regarding resource people was made in one of the earlier questionnaires. The subject was raised a second time during a meeting with the participants two months prior to the start of the course. These two requests yielded no suggestions.

The participants were faced with the same problem they had in dealing with objectives. Not knowing enough about the topic or the direction the course was going to take made it difficult for the participants to recommend resource people. Participants in both satellite groups and in the control group experienced the same dilemma.

Suggestions for subject specialists finally started coming mid-way through the course. Unfortunately, this left little time for the person invited to free himself from his regular duties, to be briefed on the nature of the medium and the course, and to make the necessary preparations for the learning activity he was to conduct. Some guests presented prepared lectures, others used a question and answer format while one conducted a simulation exercise. Each satellite group had three guests averaging an hour each. The face-to-face group had two guests presenting and directing activities for two hours each.

A small problem that arose in connection with student-invited guests was that one of the guests who was most appealing to one group of participants, had no appeal for another group. On only one occasion was there an inability to reach consensus regarding who should be invited. The conflict in this case was over the suitability of the resource person rather than over the subject matter he was to deal with. The resolution of this conflict was that those opposed to his appearance did not attend his presentation.

Instructional Aids

The participants' questionnaires provided the course designers with an outline of the course material. This data was researched, supplemented and organized into the previously mentioned textbook and book of specially selected readings*. In addition, in each location there was a filing cabinet containing copies of over 60 articles pertaining to long-range planning. Participants were encouraged to read these articles as background information for class discussion and presentations, and as a means of meeting objectives unique to their own particular situation.

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* See Addendum 1, Forward Planning in Government; and Addendum 2, Forward Planning: Selected Readings.

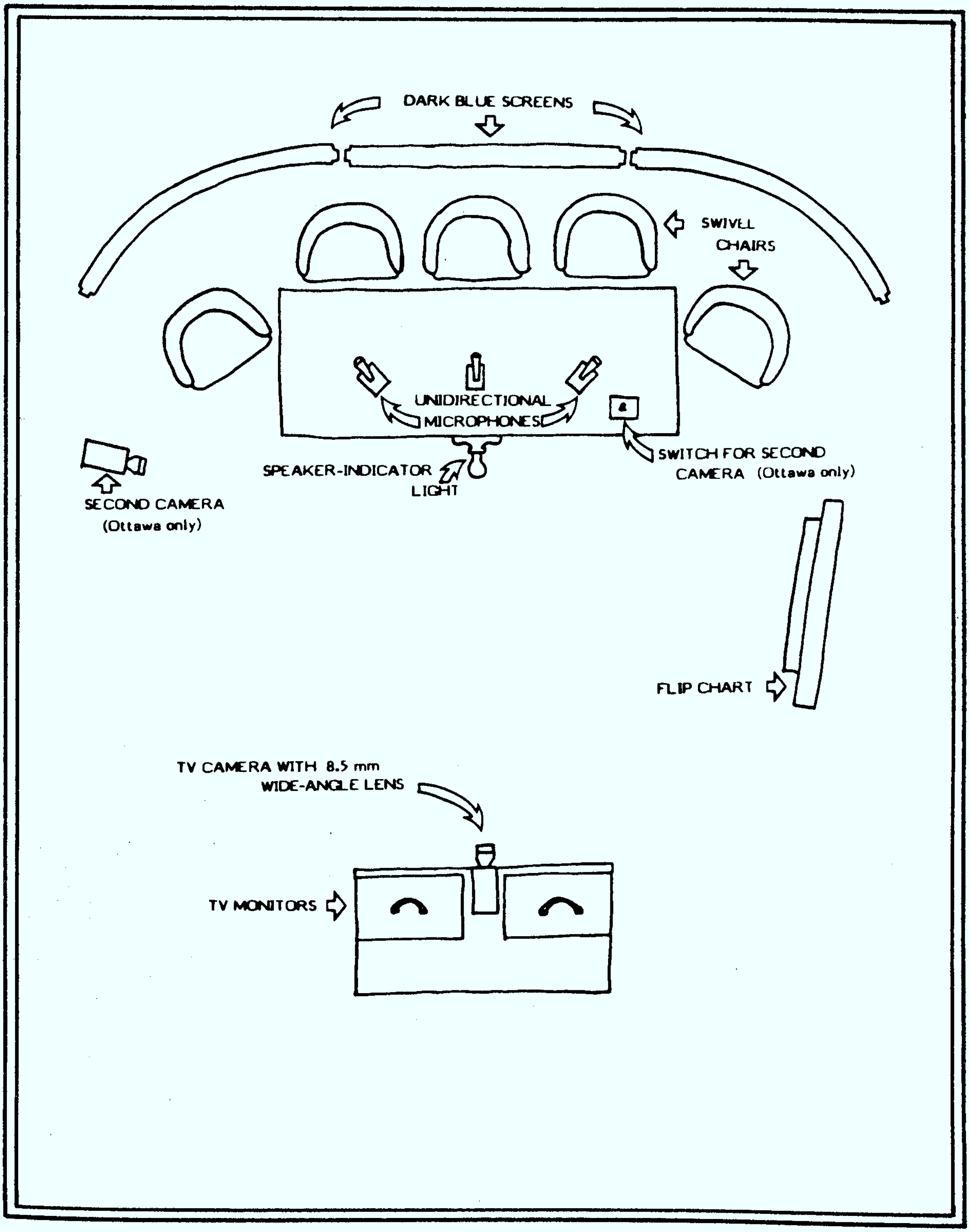

Figure 2
Teleconferencing room

In the Ottawa location a second camera was installed to transmit writing or other graphics displayed on a flip chart. This camera could be conveniently switched on by either a participant or a course director. (See figure 2). The Ottawa group in both satellite courses made frequent use of this second camera to transmit graphics. In St. John's where there was only a single stationary camera in each location, attempts were made to transmit graphics by moving a flip chart into the range of the camera. A lack of initial success in transmitting flip chart graphics resulted in the St. John's participants from the second course abandoning any further experimentation with this technique. This had not been the case with the St. John's participants in the first course. They used the flip chart as frequently as they felt it was necessary and simply compensated for poor picture quality by giving a brief explanation.

Facsimile terminals to transmit printed material were installed in St. John's and Ottawa to augment the audio-visual communication. Some use was made of this facility to transmit articles and handouts, but the quality of the copy and the frequent breakdowns precluded extensive use of this equipment.

Course Directors

The student-directed orientation of this course demanded that the course directors be non-directive and group centred. It was necessary at the beginning of the satellite courses for the course directors to spend a fair amount of time explaining the nature of the medium and the procedures that had, in the past, been found appropriate to it. At the same time they encouraged the participants to experiment with new ways of exploiting the potential of the medium.

In spite of the acceptance by the participants of a student-directed course some of them still expressed a desire for the course directors to deviate somewhat from this methodology. They asked for the course directors to lay down the schedule of activities, to name and arrange for visits by subject specialists and to keep a tight rein on discussion. In addition, some expressed a desire for an opening lecture summarizing the main aspects of long-range planning. These reactions to the role of the course director did not, however, prevent these participants from becoming involved in and deriving considerable benefit from a student-directed course.

In attempting to facilitate the attainment of the course objectives the course directors never felt quite satisfied with the speed at which the course was going.

Learner

In a student-directed course one of the most important responsibilities of a course director is to ensure that the participants have a clear understanding of their roles. In spite of pre-course meetings, activities were well under way before the participants fully appreciated the extent to which the course directors would go in surrendering their customary authority.

Not all participants were prepared to take responsibility for suggesting or contacting subject specialists, or to make a contribution to the preparation and delivery of class presentations. It appeared that participants on the satellite courses were more willing to adopt the required learner roles than were the participants in the control group. This could be attributed to the fact that the satellite participants worked in small groups that were physically removed from one another, thereby promoting a feeling of independence. The control group, on the other hand, found themselves situated in a conventional classroom and, therefore, tended to display conventional classroom behavior.

Although the satellite participants in general functioned well on their own, those in the first session relied heavily on the technology, in that, they were dependent on continuous communication with the course directors. This was brought home most forcibly when, on one occasion, lightening struck a ground station, temporarily knocking out the satellite link. Word was passed along to the participants by phone that they were to carry on working in their separate groups. The Ottawa group, which included the course directors, did precisely this, but the other four groups met briefly, decided they could not operate in isolation and left without having attempted any learning activities.

The participants on the second course seemed to be less dependent on the technology and ignored most sound and picture troubles which threatened to interrupt communication. Their confidence in the technology could perhaps be a reflection of the increased confidence that the course directors had in the system they had used for four weeks. Also, by the beginning of the second course an audio teleconferencing back-up system had been installed. This measure guaranteed that instruction could continue in the event of problems with the satellite.

Appendix B contains an example of what one participant was motivated to do as a result of the course. It is a detailed long-range plan for his specific area of botanical research in the Department of Agriculture. He prepared this plan in the weeks immediately following the course. Although his efforts might be considered exceptional, the plan that he produced is indicative of the potential for learning that was available to all the participants.

Interaction and Decision-Making

The learner's decision-making was facilitated by the elements noted in figure 1. The need to set objectives, to lay out schedules and to build a feeling of rapport provided a period of time during which the learners became used to the technology. As the chief learning activity was one which required all of the students in each group to contribute to the material being studied, group interaction was promoted, first of all within the group during preparation time and ultimately among the groups during the presentations.

The course directors noted the difficulty in the group decision-making process when it came to deciding on inviting subject specialists. In general, the learners had worked effectively in developing learning activities and in using instructional aids, but when it came to deciding on the subject specialists they displayed a reluctance to offer suggestions. When suggestions were made, discussion was hesitant and consensus was not easily arrived at. The problem of deciding on subject specialists could be attributed to the fact that the learners did not know any specialists, they felt awkward imposing their personal preference on the group, or they were uncertain that the specialists they did know would answer the needs of the group. This dilemma resulted in a deviation from a strictly student-directed approach in the case of the face-to-face group where it was the course directors who assumed responsibility for inviting subject specialists. Although there were similar difficulties in the satellite groups, they were eventually resolved and the participants made arrangements for subject specialists to attend the course.

Conclusion

A factor that was continually coming to the course directors' attention was the need for all those involved to understand what was expected of them. In the conventional classroom there is seldom any speculation about the responsibility of the learner and the responsibility of the teacher. Years of conditioning have engrained modes of behavior and expectations. The special approach to learning demanded by a student-directed course requires a deliberate and continuous effort if these years of conditioning are to be overcome. These particular characteristics of student-directed learning would appear to apply not only to its use in satellite courses, but to its use in conventional face-to-face classroom situations as well.

STAFF TRAINING BY SATELLITE:
AN EXPERIMENT IN THE
USE OF INTERACTIVE TELEVISION

COURSE DESIGNERS'/DIRECTORS' REPORT NO. 2

GLENN BARKER

AND

TERRY McCOY

Introduction

This report contains the observations of the designers/directors of a staff training course which was run for an experiment using a Communications Technology Satellite link between Ottawa and St. John's, Newfoundland.

The experiment involved teaching a course in long-range planning, simultaneously, to groups of managers in five different locations. There were four locations in St. John's and one in Ottawa, with four participants in each location. The members of each group communicated with the members of the other groups by means of interactive television. The two course directors were in the Ottawa location. Two different 16-hour courses were conducted in this manner. A third course dealing with the same subject matter was given in a conventional classroom to a control group of twenty participants.

Teleconferencing Rooms

The general arrangement of furniture and equipment in the five teleconferencing rooms is shown in figure 2 of the preceding report *. During the course various modifications were made to increase the effectiveness of the medium.

The original dark walls in the Ottawa room and the dark screens behind the participants' chairs in St. John's did not reflect enough light to provide a good TV picture. To remedy this problem, in St. John's, the background screens were removed. The light colored walls, which then served as the background, improved the picture quality considerably. A further improvement resulted from the covering of dark colored doors with large sheets of white

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* Report No. 1, "Staff Training by Satellite: An Experiment in Student-Directed Learning", Page 10.

paper. In Ottawa, where the walls themselves were painted dark red, the problem was resolved by hanging long sheets of white paper across the entire background. This change caused a Newfoundland viewer to ask whether floodlights had been installed in the Ottawa location.

All the lighting in the room was provided by two rows of double tubed flourescent fixtures recessed flush with the ceiling. The rows of fixtures spanned the width of the room, one directly above the participants' table and the second one three feet in front of it. To prevent light from shining directly on the monitors the second row of lights was turned off. To further reduce glare, an 18-inch curtain was suspended from the ceiling just in front of the row which was still providing light for the room.

Monitors

Each of the five locations was equipped with four TV monitors. These monitors were arranged in pairs one on top of the other as shown in figure 2*. They were 26-inch Sonys fitted with long-persistence green phosphor picture tubes. This type of tube produces a greenish image like that which one associates with radar scopes. The benefit of the long-persistence tube was that it held an image on the screen for a slightly extended period of time. This was necessary to improve the picture quality which was slightly degraded by the process of multiplexing four channels into a single channel for satellite transmission.

* Ibid.

One long-persistence blue phosphor tube was tried in the Ottawa location. Although there was no definite agreement that it provided a better picture than the green, it did provide one that more closely resembled what the participants were accustomed to with black and white television.

Midway through the first course, glare was reduced and contrast increased, for the Ottawa viewers, by the addition of a shield of black construction paper which projected from the top and sides of the monitors. This simple modification was quite effective.

Speaker-Indicator Light

Cards bearing the participants' names and corresponding to their seating arrangement were fastened over the monitors allowing a viewer to associate a name with the speaker even though distinctive facial features were difficult to discern. This worked of course, only after the viewer had found the speaker. Generally, however, the location of the speaker was not readily apparent and was determined only after a time-consuming scan of the four monitors.

To facilitate immediate identification of the speaker, a sound-sensitive indicator light was introduced near the end of the first course. It was installed under the front edge of the participants' table and was activated by the sound of a person's voice. (See figure 2*) Through trial and error, it was found that a 25-watt red light bulb was bright enough to be easily seen, but not too bright to be distracting. Some adjustment to the switch mechanism had to be made to prevent the light from being triggered by minor noises in the room and to make it stay on through short pauses in the middle of a continuing utterance.

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* Ibid.

Microphones

Each room was equipped with three AKG unidirectional microphones as shown in figure 2*. To accommodate a speaker who wished to speak while at the flip chart in the Ottawa location, an additional microphone was fixed to the leg of the flip chart stand.

To encourage spontaneous interaction the microphones were open at all times. Other systems could have been used, such as those which are voice activated or which require the pushing of a button to open the microphone. These systems, however, have the drawback of inhibiting comments and interjections from other participants. With the open microphone system used in this experiment, conversation proceeded in a very natural manner. The rapport that developed among the participants in the five locations could be directly attributed to their ability to communicate as freely as if they were all in the same room.

Headphones

The participants wore headphones to overcome the problem of feedback which would have occurred if loudspeakers had been used with the open microphones. The headphones were all light weight AKG's with individual volume controls. The cables on them were long enough to allow a wearer to leave the table and go to the flip chart without having to remove his or her headset.

The participants, in general, were not bothered by having to wear headphones, although a few did mention that the headphones required getting used to. One participant with a hearing problem pointed out that individual volume controls

* Ibid.

for each ear piece would have been more beneficial than the AKG's single control.

On a couple of occasions unused headphones, inadvertently left on the table near a microphone, produced feedback of the type that the use of earphones was intended to eliminate. This experience resulted in a standing procedural rule whereby all unused headphones were to be kept off the table.

In spite of all the precautions taken during the second satellite course, the feedback problem was experienced off and on, but it was seldom severe enough to interfere with the interaction. This feedback was the result of adjustments having been made within the audio system to permit the possibility of using a telephone landline as a backup in the event of temporary satellite shutdown. This tampering with the original adjustments in the audio system was not fully rectified until the very end of the second course.

Cameras

Each of the four St. John's teleconferencing rooms was equipped with a Sony video camera fitted with a wide-angle lens. (See figure 2*) To eliminate the necessity of having a cameraman, each camera was set up in a fixed location. As the participants were not to touch the equipment they experimented with getting larger pictures by either moving the whole group or an individual closer to the camera.

In the Ottawa room, in addition to the fixed camera, a second camera was set up to provide close-ups of guests and flip chart material. Switching

* Ibid.

from the fixed to the second camera was controlled at the participants' table. (See figure 2*)

Flip Charts and Graphics

The second camera proved particularly useful as a means of silently signalling speakers to identify themselves after they had begun to speak. This was done by switching to the second camera which was focussed on a flip chart picture of a figure waving his arms, the implicit message being that the hearers were at a loss as to who was speaking.

The flip chart in the Ottawa room was also used by the course directors, and the participants in much the same way as it would be used in a conventional classroom. It served as a complement to an oral presentation or as a means of setting out instructions. As long as the writing was done with bold lines and the lettering was about two inches high, it was legible over the system.

The participants in St. John's attempted to use a flip chart without the benefit of a second camera and did so, in the case of members on the first course, with considerable success. What is of particular interest is the way in which an initial success operated as a source of motivation for further attempts. One of the St. John's participants used a flip chart early in the first session and was quite successful in doing so. The flip chart was moved up to a point in front of the camera where it would produce the largest image possible while remaining in focus. The best picture was achieved when the flip chart stand was brought from its normal sloped

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* Ibid.

position to a position perpendicular to the floor. In this position glare from overhead lights was eliminated. This success seemed to encourage others who, during the rest of the first course, frequently made use the flip chart. The St. John's participants on the second satellite course, on the other hand, refrained from using the flip chart after one of them experience an early unsuccessful attempt. This lack of success was due to the fact that the participant had put too much data on a single page. It was illegible when transmitted over the system.

On three occasions, the flip chart in the Ottawa location served to overcome temporary audio problems. In these cases messages which were written on the flip chart were transmitted by means of the second camera.

Back-up Systems

Facsimile equipment to transmit printed or graphic material had been installed in the Ottawa location and one of the St. John's locations. Although available as a back-up and as a vehicle for augmenting the satellite link, it was seldom used because of the poor quality of the copies it produced and because of the delays in repairing breakdowns. A second back-up system was installed using telephone lines. Had there been a breakdown in the satellite system it would have been possible therefore to fall back on an audio teleconferencing link.

VTR

The only instructional material that did not originate from one of the teleconferencing rooms was a 30-minute video tape recorded lecture. It was transmitted throughout the system from the Ottawa control room. The video quality of this program was exceptionally good in all locations. Some technical problems resulted in the transmission of a poor audio signal to St. John's.

Conclusion

The audio teleconferencing system was not available as a back-up during the first course. The lack of this facility as well as intermitent difficulties with the satellite, caused a continuing uneasiness among the participants. They were never quite sure if the next lesson would take place as scheduled. However, the installation of the audio back-up, combined with the satellite team's increased confidence in and experience with the system all served to virtually eliminate apprehension from the minds of the participants in the second course. Whereas the participants in the first course seemed to be very conscious of the possibility of problems in the system and were readily thrown off by noise in the audio channel or by a loss of video, the participants in the second group almost never allowed interference, such as static or picture break-up to interrupt their communication. These observations lead to the conclusion that among the most important factors for the users of such a system is their desire to communicate combined with a confidence in the system's capacity to accomplish this.

Appendix A

Appendix A, "A Simulation of Staff Training by Satellite" describes the pilot course conducted four months prior to the satellite experiment.

A SIMULATION OF STAFF TRAINING BY SATELLITE

The writers of this report would like to set out some of their observations made as course directors on a pilot study into an innovative use of teleconferencing as a training technique. This technique will enable learners in various remote locations to participate interactively, via satellite, in the same learning activity.

THE SATELLITE EXPERIMENTS

During the months of April, May and June, 1977, the federal government's Public Service Commission, the Department of Communications and Memorial University will be conducting experiments via the Communications Technology Satellite (CTS). In these experiments public servants and university personnel in five separate locations will follow the same staff development course televised via satellite. Four classroom will be located in St. John's Newfoundland while the fifth classroom will join the network from Ottawa. During the course each student will be able to see and interact with all other participants in all other locations.

There will be two experimental courses given, in each of which there will be 25 participants, five in each classroom. Each experimental course will consist of eight two-hour satellite sessions. In addition to these sessions, provision has been made for each group to work off-camera for two hours prior to their use of the satellite. A control group consisting of one class of 25 students will be taught at the same time under normal classroom conditions.

METHODOLOGY

The instructional methodology derives from a Rogerian educational philosophy of student-directed learning. In this application of the student-directed approach,the students were given an opportunity to choose the subject-matter of their course. They decided upon "Long-Range Planning". Following the selection of this topic they indicated through responses to questionnaires and through interviews a number of specific topics that they would like to deal with. Student involvement in the selection of subject matter is to continue until the completion of the course.

Student initiative was also sought in finding content specialists. Some students indicated that they can either provide a special expertise themselves or that they are willing to arrange to bring in specialists from either St. John's or Ottawa.

PILOT COURSE

In order to test the student-centred teaching of long-range planning over an audio-visual teleconferencing system, a pilot course was held in early January,1977. Working under simulated satellite conditions,sixteen public servants participated in a three and a half-day residential course dealing with long-range planning. During the course, four groups of four participants each, communicated with each other via closed circuit TV. The total time on TV was equivalent to the sixteen hours that the Ottawa-Newfoundland students will experience.

Although one might have expected that the intense use of TV would be excessively demanding on the students, this was not found to be the case. The interactive nature of the system was so effective in permitting immediate, direct and spontaneous communication among all students and course directors, that after the first day many of the participants reported that they were oblivious to the fact that they were dealing with one another via TV. This use of the medium is far removed from the purely receptive, one-way transmission usually associated with commercial and educational television broadcasting.

VARIATIONS TESTED

For most of the TV activities,all four locations interacted with each other. This particular configuration was particularly appropriate for presentations by resource people, reports of group work and general discussions and de-briefings. On four occasions the four groups were linked in pairs with the video feed continuing into all four locations. In this way each group was able to see all others but was able to speak with only one other group.

Other variations in our satellite simulation proved popular:

1. Video tape recordings of a live lecture and of a film were successfully transmitted over the system.

2. In one room a change in furniture from large sofa-like chairs to small tables in front of straight chairs brought the students closer to the camera and appeared to increase their participation.

3. In order to get a close-up of a guest speaker, he was provided with a chair on casters so he could move it to a predetermined location closer to the camera.

4. In order to supplement presentations with graphic material a second fixed camera was set up in one of the rooms. The speaker switched to the second camera when he wished to write on a flip chart.

PARTICIPANT EVALUATION

During the pilot course, the students filled in questionnaires which surveyed their reaction to various aspects of learning through audio-visual teleconferencing.

In evaluating the course two-thirds of the students found that the use of the technology for educational purposes was in no way disruptive, the other one-third found it only slightly so. More than three-quarters of the students strongly disagreed with the statement that the system inhibited spontaneous participation.

With ordinary classroom lighting and a fixed camera focussed on a group of four or five students,the distance between the camera and the students was too great to allow a viewer to pick up many non-verbal cues. Nevertheless, the students appeared to compensate in various ways for this lack of information and managed to communicate in a manner that was virtually as effective as face to face communication. For eighty-three per cent of the students, a less than ideal visual image proved to be no distraction during ongoing conversation. In spite of the reduced visibility of non-verbal cues, the system did not demand a greater degree of concentration, nor did it lead to frustration or lack of participation by anyone wishing to offer an opinion, or comment or an item of information.

With this particular audio-visual system, students were not required to press buttons or flip switches before contributing to an ongoing conversation. However, they did have to wear light-weight earphones to overcome the feedback problem created by the open microphone. The mild inconvenience reported by a few participants was not sufficient to interfere with their learning experience. In general, the students reported that conversation could be carried on in an easy, friendly and cooperative manner.

When students were asked for their impression of whether any one group dominated the discussions, there was an almost unanimous opinion that each group participated to the same extent. There was no significant difference in the influence of any one group on all others, nor was there any one group that students indicated a desire to belong to. These reports substantiate the subjective impressions gained by the course directors.

In response to other questions, students indicated a definite need to clearly establish at the very outset, the way in which this course would meet his or her objectives. As this step comes at a time when the students still feel unsure of how to use the system, the course directors must impress upon them the importance of expressing their needs and expectations.

Not having the structure of a regular classroom, there seems to be an even greater need to work out a learning contract with the students. This contract should specify what is to be involved in the course; that is, the objectives, the role of the course directors, the types of activities, the human and material resources, and a specific schedule.

In spite of the use of interactive television, the students still wanted the course directors to play a role similar to that played by course directors in conventional training sessions. The course directors were expected to act as moderators. In this role they would give direction to the overall course, introduce and sum up individual sessions, make periodic formal presentations, and provide continuity. They would also insure the active participation of all students, and provide immediate feedback or evaluation when necessary. Under these circumstances informality, receptiveness and flexibility would be important assets for course directors using a student-centred approach.

Although the pilot course aimed at two-hour on-camera sessions, the TV time sometimes extended beyond this period. On one occasion a session went on for three hours with no decline in student interest or participation. In fact the session was continued at the request of the students who wanted to complete the activity in which they were involved. The student questionnaire revealed, however, that the students considered one and a half to two hours the optimal length of on-camera time.

SUGGESTIONS AND RECOMMENDATIONS

As a result of this pilot course the course directors have arrived at the following conclusions with regard to the future use of audio-visual teleconferencing for training purposes.

The technological aspect could be improved in the following ways:

- Each TV monitor should be equipped with a light which would come on automatically to indicate which screen the speaker is on. This would eliminate the frustration that arises when a viewer cannot immediately locate the source of an interjection.
- A second camera should be available in each room to transmit graphics.
- The ability to change from having all locations linked together to having them linked in pairs or in groups of threes would add a considerable degree of flexibility to future satellite training.
- TV monitors are scanned more easily when arranged side by side at eye level than when stacked one on top of the other.

The use of interactive TV increases the importance of the following points related to the instructional methodology.

- Initially, there is more communication with participants in remote locations than with the participants in one's own room. For this reason an opportunity should be provided for the members of each group to get to know one another before the first on-camera session.
- Due to the dispersed locations of the students it is important that all activities be coordinated by a moderator. This person could be the course director or someone appointed by him or by the students themselves.
- There should be a schedule agreed to at the outset and pains should be taken to adhere to it.
- The scheduling of time during each TV session must include time for feedback or evaluation.
- If there is to be an overall evaluation of the course, it should be built into the schedule and should be thoroughly explained to the participants.

As a preparation for the satellite experiments the pilot course was invaluable. If the satellite experiments themselves can also contribute significantly to our understanding of this medium and to our skill in the use of it, a contribution will have been made toward the development of a training system capable of reaching people in every region of this country.

GLENN BARKER

TERRY McCOY

Appendix B

Appendix B sets out a long-range plan for a research program into the potato wart disease. This long-range plan was prepared by one of the course participants, Michael Hampson. The Management Planning System presented in Forward Planning in Government, Addendum I, provided Dr. Hampson with the analytical framework on which he constructed his long-range plan.

POTATO WART DISEASE RESEARCH PROGRAM

(LONG-RANGE PLANNING EVALUATION)

M. C. HAMPSON

RESEARCH STATION
ST. JOHN'S, NFLD.

MAY, 1977

CHAP. 1 SITUATION ANALYSIS

I. Mandates

II. Internal Operations
   A. Structure
      1. Organization
      2. Degree of Centralization
      3. Channels of Communication

   B. Personnel
      1. Management Development and Effectiveness
      2. Number of Employees
      3. Capabilities
         a. Skills
         b. Experience
         c. Expertise
         d. Education
      4. Attitude
      5. Performance

   C. Operations
      1. Management Philosophy
      2. Policy Guidelines
      3. Departmental Procedures
      4. Recent Historical Development
      5. Administrative Workload vs. Mandated Tasks
         a. Time devoted to each
         b. Resources devoted to each
      6. Response Time
         a. Requests for Supplies
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         c. Product or Result requests

   D. Physical Facilities
      1. Accommodation
      2. Technology

III. External Factors
   A. Government Factors
      1. Federal Department
      2. Provincial Government
      3. Local Government
      4. Overlapping Mandates
      5. Policies and Procedures
         a. Treasury Board Guidelines
         b. Program Priorities
         c. Exceptions/Exemptions
         d. Program Planning Budgeting System
         e. Operational Performance Measurement System
         f. Management by Objectives
         g. Cost Benefit Analysis

B. Human Factors
   1. Population Growth Rate/Profile
   2. Social Issues
   3. Client Needs
   4. Client Satisfaction
   5. Employment
      a. Skilled/Unskilled
      b. Mobility
      c. Unions

C. Economic Factors
   1. Revenue Available
   2. Rate of Taxation
   3. Market Considerations
   4. G. N. P.
   5. Inflation Rate
   6. Land/Buildings/Supplies
      a. Cost
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D. Technological Factors
   1. Transportation
   2. Communication
   3. Equipment/Machinery

E. Environmental Factors
   1. Geographical Location
   2. Climate
   3. Urban/Rural

CHAP. 2 PROJECTION

I. Assumptions
   A. Background
   B. Articulation

II. Formulating Objectives/Goals
   A. Statement
   B. Program
   C. Program-related Objectives

III. Key Result Areas
   1. Client Satisfaction
   2. Productivity
   3. Innovation
   4. Resources
   5. Management Development
   6. Employee Attitude
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APPENDIX

A. Contexual map of potato wart disease research program

B. Irrigation

1. Aim

2. Origin

3. Tasks
   a) Scheme I
   b) Scheme II
   c) Scheme III
   d) Scheme IV
   e) Scheme V
   f) Scheme VI
   g) Scheme VII
   h) Scheme VIII
   i) Scheme IX
   j) Scheme X

4. Influence diagram

C. Additional hosts

1. Aim

2. Origin

3. Tasks
   a) Cultivar testing
   b) Genera testing
   c) Inoculation method
   d) Irrigation method
   e) Inoculum density
   f) Time after inoculation
   g) Cultivar confirmation
   h) Maturity
   i) Temperature
   j) Races
   k) Day length

4. Influence diagram

D. Inoculum density

1. Aim

2. Previous Work

3. Work Strategy

4. Tasks
   a) Inoculation
      i. Techniques
      ii. Approaches
   b) Sporangial number
   c) Sporangial age
   d) Contact time
   e) Sprout age
   f) Sprout length
   g) Sprout No.
   h) Temperature
   i) Moisture
   j) Day length
   k) Tuber age
   l) Soil type
   m) Soil amendments
   n) Race/Cultivar

5. Influence diagram

CHAPTER 1

POTATO WART DISEASE RESEARCH PROGRAM (PWDRP)

SITUATION ANALYSIS

I. MANDATES. BRANCH GOAL:-

"Through the development of superior varieties and improved management practices and control of virus diseases to improve the unit yield of POTATOES by 5%, while maintaining or improving the required standards of fresh and processed quality".

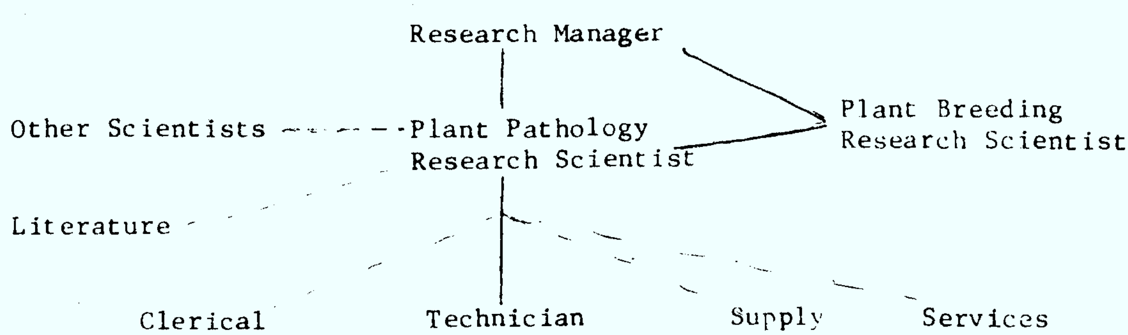
STATION GOAL:-

"To identify factors affecting the development of potato wart fungus under Newfoundland conditions and to develop methods for economic control of the pathogen".

II. INTERNAL OPERATIONS.

A. STRUCTURE:

1. ORGANIZATION



2. DEGREE OF DECENTRALIZATION.

Personnel directly connected with the PWDRP are centralized at the Research Station. Most supplies are imported.

3. CHANNELS OF COMMUNICATION.

a. FORMAL:- Letter, inter-office memo and requisition form.

b. INFORMAL:- Verbal, inter-office and external telephone systems.

B. PERSONNEL:

1. MANAGEMENT DEVELOPMENT AND EFFECTIVENESS.

Most development follows on-the-job contingency occurrence. In-house training courses occur sporadically. Management effectiveness is high since there are short paths in vertical management and low number of personnel directly involved in the PWDRP. There is always room for development. Technician training is limited to on-the-job training with time out for subject-related College courses.

2. NUMBER OF EMPLOYEES.

For the PWDRP, one scientist and one technician are allocated.

3. CAPABILITIES.

a. SKILLS:- Supervisory skills, largely employed by the Research Scientist, exists for program and project-development based on observation and hypothesis, work-development in terms of experiments to be carried out, and results-development into publications.

Skills are for adaptability to changing phases of the program, to continually modify program toward objectives, to maintain high levels of laboratory work in quality, quantity, effectiveness and scholarship. Technical skills encompass ability to perform experiments, operate sophisticated equipment, record work completion and results achieved, and to organize different aspects of the daily schedule.

b. EXPERIENCE:- Supervisory and laboratory experience, experience in handling equipment and chemicals, experience in designing experiments are evident.

c. EXPERTISE:- Specialized expertise is used in designing work so that the program contributes to the State of the art of the Potato Wart Disease Problem, and also is cognizant of current advances in other geographical areas. Technical expertise is used in maintaining the flow of experimentation and accumulation of results.

d. EDUCATION:- Research Scientist education is at Doctorate level, and technician education is at the Diploma level.

4. ATTITUDE.

The result-producing program is developed through a 'research attitude'. This means to be adaptable to failure, to work in a continued cycle of processes over different time-length bases, to work without seeing tangible results accrue, and to have faith that 'good' will eventually come of all the endeavours.

5. PERFORMANCE.

Jobs are carried out with maximum efficiency, having due regard to safety and hazards, timing and overall organization. High levels of performance are sometimes hard to achieve when results are often small, far between and sometimes up a "blind alley". Performance is measured by results incorporated into publications and by positive feedback of requests for reprints.

C. OPERATIONS:

1. MANAGEMENT PHILOSOPHY.

Realization of the overall aim of the Branch, realization of the objectives and goals, and realization of the Station objectives and goals through support of the individual scientists contribution to these aims by contributing monetarily to the projects and fostering a working climate to ensure success of the endeavours. In the PWDRP, many small results may accrue before a substantial direction can be developed, and it is management's philosophy to accept the time-base over which this happens. On-the-job management philosophy is concerned with developing and maintaining momentum to cyclical research processes and to expand the experimentation to fill the time available within strictures imposed by apparatus, facilities and the knowledge that one is dealing with living organisms that have no comprehension of man's desire for organization, orderliness and logic.

2. POLICY GUIDELINES.

Not directly applicable to the program.

3. DEPARTMENTAL PROCEDURES.

Results are accumulated and digested into publications through mediation of the Research Manager. Departmental procedures no doubt operate at several levels of the program albeit subtly.

4. RECENT HISTORICAL DEVELOPMENT.

Within the PWDRP all present events are predicates of the past. Since the work advances by results built on past experiments, no single dominant event can usually be culled out. However, as a result of careful experimental planning events do arise which cause the program to settle into certain directions. Other historical developments include the acquisition of pieces of equipment which speed the production of results or speed the processes involved in routine experimental procedures. Since research is an open-ended activity the factor of "recent historical development" is of paramount importance, probably the most singly important factor. A striking result causes the PWDRP to proceed down an unknown channel setting up waves and ripples of unforeseen experimentation. Since research proceeds by discovery, "recent historical development" is ultimately highly influential on the mandate, for if a problem singled out for solution is solved its raison d'etre disappears.

5. ADMINISTRATIVE WORKLOAD vs. MANDATED TASKS.

a. TIME DEVOTED TO EACH:- Little time is involved in administrative work (less than 5% per annum).

b. RESOURCES DEVOTED TO EACH:- Administrative resources are readily available. Mandated-task resources are not necessarily readily available: tubers must be planned for and grown for experimentation; inoculum for infection is usually developed in situ in greenhouse work. Glassware and chemicals are imported; the time base between demand and supply varies very much with the nature of the resource and the supplying company. Equipment requests are influenced by the availability of Station funds, by the current market demands on a material or international level.

6. RESPONSE TIME.

a. REQUESTS FOR SUPPLIES:- This is often a function of the request and is subject to wide range of variables and variation.

b. WORK REQUESTS:- Usually there is little lag between stimulus and response in the unfolding of the program. Time is a function of the nature of the request, a function of current jobs, and a function of future time assumed to be available.

c. PRODUCT OR RESULT REQUESTS:- Response time is subject to a host of variables since some of the experimentation may exist over a long time base, and, as time proceeds, may generate more of the same or branch work that also extends the originally envisaged time base.

D. PHYSICAL FACILITIES:

1. ACCOMMODATION.

The PWDRP takes place almost entirely within a laboratory/greenhouse complex that is separated from the main Station building as the disease is quarantinable. Prevention of the disease moving into the Station grounds is a superior philosophy to that of cure, since there is no cure save that of destroying the ground to render it unfit for crop growth. The organism causes an insiduous soil-borne disease.

Within the complex are a greenhouse, a controlled environment growth room, a 'cold-room', a small and a main Laboratory. This houses one Research Scientist and one Technician. The greenhouse contains six growth benches.

2. TECHNOLOGY.

To bring about a realization of the mandate, and to break the mandate down into parts applicable to the PWDRP, a variety of research tools are available. The greenhouse soil benches are equipped for irrigation and controlled temperature work, and irradiated by fluorescent tubes. The growth room is equipped to control ambient temperature, light quality and duration, watering and levels of humidity. The cold room contains shelving to maintain tubers, and other living materials at constant near-freezing temperature. The header house is equipped to pot plants, store soil supplies and flat and pot supplies, fertilizer, etc. The small laboratory deals with soil-shaking and sieving, centrifugation, lyophilization and vacuum distillation. In the main laboratory, equipment is installed for ultra-violet irradiation of microscope samples, column and thin layer chromatography, sample fractionation, clean-air incubation, incubation and refrigeration of samples and chemicals, distilled water production, sterilization, and other processes. Chemicals and inoculum samples are prepared using standard equipment.

To produce the results the activities are divided into those associated with infectivity wherein generally tubers (or sprouts) are inoculated via irrigation, controlled soil temperature and pot work, and those associated with viability. In the latter, sporangia are treated with chemical incubants derived from tubers and analyzed through a variety of analytic procedures.

Gas, electricity and water supplies are readily available.

III. EXTERNAL FACTORS.

A. GOVERNMENTAL FACTORS:

1. FEDERAL DEPARTMENT.

The PWDRP is carried out under a mandate set up by the Research Branch, Agriculture Canada. The disease is controlled by Act of Quarantine. Under these conditions, soil and soil produce is prohibited from being moved out of Newfoundland. Inspection and vehicle-washing facilities maintain quarantine control. Quarantine is the first line of disease control-preventing the disease moving into a host crop area. Entire funding for the PWDRP is Federal.

2. PROVINCIAL GOVERNMENT.

There is no input from Provincial Government for research nor quarantine.

3. LOCAL GOVERNMENT.

No input.

4. OVERLAPPING MANDATES.

These do not exist. All the PWDRP work is carried out in Newfoundland under one mandate.

5. POLICIES AND PROCEDURES.

a. TREASURY BOARD GUIDELINES:- Influence the level of spending that the PWDRP imposes. The level of spending is pegged and is influenced by a number of other variables.

b. PROGRAM PRIORITIES:-"Research Branch 'Research and Development Plans', Objective 3, Goal 4, POTATOES", out of 16 areas listed in descending order of priority, #5 is "Breeding wart and nematode-resistant potatoes for Newfoundland". Within that priority the PWDRP exists as part of the breeding program. The breeding and pathology programs are essentially parallel and different aspects of what has come to be termed, "The potato wart problem". The pathology leg is, therefore, viewed as an extension of the breeding program. This view is interpreted as the belief that breeding is the answer to the "problem", and that the PWDRP supplies information about the infectivity of the organism and its possibility to be controlled by means other than by breeding, since breeding never provides an ultimate solution but, by the nature of interacting organisms, a stop-gap of long, sometimes short duration. A recent historical development that underlines this fact is the occurrence over the last 2-3 decades of biotypes that infect otherwise resistant cultivars.

c. EXCEPTIONS/EXEMPTIONS:- Not applicable.

d. PPBS:- Not directly applicable.

e. OPMS:- Not applicable.

f. MBO:- The Research Branch allocates its programs along MBO lines. The PWDRP belongs to Objective 3: Horticultural Crops, "To improve the efficiency of production and the quality of horticultural crops", Goal 4: "By 1982, to have developed new information and technology, that will make possible an increased unit yield of potatoes by 5% while achieving higher standards of fresh and processed quality, through the development of improved cultivars, pest control and better management practices (From 1977)"; Station Goal 3.4.5, "To identify factors affecting the development of potato wart fungus under Newfoundland conditions and to develop economic control of the pathogen".

g. CBA:- Not directly applicable.

B. HUMAN FACTORS:

1. POPULATION GROWTH RATE/PROFILE.

This is of no particular influence on the PWDRP. Indirectly, an increase in home gardening (including potatoes) increases the chances of disease-spread (via inoculum transfer) and lends support to the need to increase the amount of information available on the disease under Newfoundland conditions, thus applying - obliquely perhaps - pressure to the program.

2. SOCIAL ISSUES.

There is a need to be able to produce potatoes without the danger of them contracting the disease. In this sense, oblique again, society exerts a pressure and thus influences the thinking on the program. The disease is a social one in the sense that it exists wherever there are people and allotment gardening. Were it not for this fact there would not be a PWDRP. There is no demand from society, though, that the disease be eliminated.

3. CLIENT NEEDS.

This echoes the comments in the preceding paragraph.

4. CLIENT SATISFACTION.

The product of the program is a control of the disease - economical and easy, safe and certain, that can be applied. This is answered at present by the production of immune cultivars. Perhaps

"Client satisfaction" is the indicator by which the program could be judged.

5. EMPLOYMENT.

a. SKILLED/UNSKILLED:- Not directly applicable to the program.

b. MOBILITY:- Under this heading, one can use "mobility" as a further indicator - mobility of crops with freedom. It is not a direct influence, however.

c. UNIONS:- No direct influence; some small influence may be attributable in that technician input may be affected by union measures.

C. ECONOMIC FACTORS:

1. REVENUE AVAILABLE.

The program is funded from on-going research budget of the parent station.

2. RATE OF TAXATION.

Not directly applicable.

3. MARKET CONSIDERATIONS.

Not applicable directly, but since the aim of the program is healthy crops, the need for increased disease-free production adds to those factors that weigh in favour of moving the program to decisive ends.

4. G.N.P.

Not directly applicable.

5. INFLATION RATE.

Applies in the sense that for our money we can buy less tooling for the job, hence interposing a time factor between the present and a realization of the aims.

6. LAND/BUILDINGS/SUPPLIES

a. COST:- The program would reach its goals sooner if it occupied more space in that it would be possible to increase the amount of unit experimentation. Since cost is a fundamentally influential factor, it must be given considerable weight.

b. AVAILABILITY:- Land is easily available since the PWDRP is centred on the Station. Buildings is largely dependent on massive funding. Thus, the program could easily take up twice the currently available space. Supplies again are dependent on money available. Real availability is subject to the vagaries of scientific supply houses; time is again interposed. The lag that often occurs between stimulus (asking) and response (receiving) does act to influence the daily succession of events, but may not act so in a long-range sense.

D. TECHNOLOGICAL FACTORS:

1. TRANSPORTATION.

Applies at two levels: transportation is available for field work based on the program; transportation is needed for cross-fertilization of ideas in the program - since the Station is relatively isolated and considerable distances are involved in visiting parallel scientific institutions. Thus, time allocated for such visits and costs involved are also significant factors in devising program directions.

2. COMMUNICATION.

This is a logical follow-through from the preceding paragraph. Input is necessary to the life of the project. Since, as alluded to, considerable distances separate the worker here from other workers, most communication must be by letter. Telephone communication is of small weight. Likewise, inversely, foreign workers would influence the program were they to visit the facilities. Output is generally restricted to publications of findings. Discussion of findings with fellow-workers influences positively - by exposing current ideas on the "State-of-the-art" and negatively - by not being able to discuss findings and thereby retarding the program's movement.

A large library of world literature on the disease has been assembled and is used in lieu of discussive facilities.

3. EQUIPMENT/MACHINERY.

Technology, or the manner in which means are carried out, should properly follow a discussion of the tools available, therefore see II, D, 2 for a discussion of equipment. There are available a variety of techniques applicable to different phases of the PWDRP largely cullable from world literature. 'Tricks' applicable to bring about desired ends in terms of usage of equipment are largely those developed in situ since the incumbent Scientist has never met any other workers on this disease.

A compilation of techniques used and developed in the PWDRP at the Station was assembled and constitutes the technological philosophy of the program. This compilation encompasses some 30 different techniques. This technological assemblage is modified from time-to-time as better methods of handling the organism/disease develop, or as new aspects of the program emerge that need to be developed to yield information.

A running record of the technology is thus maintained and is used to influence the current approaches to the problems as they arise. In this way, a technological foundation has been brought into being that co-exists with methods and procedures which are published with findings in the on-going output phase of the program. This technological record is also used for technician-training, and ensures continuity of the program through personnel changes. (See appendix).

E. ENVIRONMENTAL FACTORS.

1. GEOGRAPHICAL LOCATION.

Potato wart disease is known to occur only in Newfoundland and Labrador, in Canada. Since the disease is also quarantined to this Province, the geographic location is a primary determinant in the location of the work. The current work is mainly in Greenhouse and Laboratory Studies at the Station.

2. CLIMATE.

Since the current studies are carried out indoors, the climate is of little influence in planning the program.

3. URBAN/RURAL.

Since we are concerned with a plant disease, all factors of geography, climate, urban and rural significance enter in. Possibly history should be included as a disease determinant because the current state of the disease in the Province is as a result of the above factors operating over a long time-base. The disease is essentially one of the field in that it is a soil-borne disease. Its occurrence is of considerable economic importance itself and is itself a primary determinant in the agricultural life of the Province: potatoes are a staple food; potatoes are imported; potatoes can, potentially, be raised indigenously to meet demand; soil products are quarantined; soils are contaminated in most of the coastal villages and sporadically in the larger settlements; the causal organism is not susceptible to conventional fungicides; the causal organism remains dormant for up to 40 years in field soil; the Province neighbours on to areas that supply potatoes on the world market.

CHAPTER 2

PHASE 2: PROJECTION

1. ASSUMPTIONS.

A. BACKGROUND

In order to articulate assumptions in the planning process for the PWDRP, it is necessary to look briefly at the background for experimental work and then to consider in detail the assumptions that arise from this background.

Initially the PWDRP sought to develop a model for optimum conditions under which the disease flourished. Under the Station Mandate, we are to identify factors affecting the development of - or responsible for the persistence of - potato wart fungus under Newfoundland conditions. (and then to develop methods for economic control of the pathogen). This point of view assumes: 1) there is a set of factors responsible for persistence; 2) persistence occurs; 3) knowing these factors, an economic control can be developed. Further, such a model would permit comparisons to be made between different sets of conditions, chemical treatments and pathogen - host interactions. This point of view, therefore, also assumes that once the proper combination of conditions was achieved, that infection would follow 100 percent wise.

As a result of several year's attempts to achieve this model, numerous occasions were noted where either or no disease developed, including a spectacular period of time in greenhouse benches when no infection could be obtained. After considerable study of these situations, it was apparent that the search for a 'model' was obscuring an obvious fact - that at times the disease was suppressed. Once this concept is accepted, a number of fairly logical consequences develop. For example, suppression of the disease is what we seek, hence a program developed along suppressive lines fairly fits this objective. Acceptance of this concept also opens up ecological areas hitherto neglected. Thus, since we detected sprout exudates, the presence of a microbiota utilizing the exudate as a nutrient supply must be postulated. Since the sprout - and the sprout is the primary infection court - must possess a characteristic 'envelope' of micro-organisms there is every likelihood of interactions between this microbiotic element and the pathogen. The disease cannot be understood nor dealt with as an entity in a vacuum, but as a resultant of the forces - host, pathogen, environment and time. If this ecological network exists (and innumerable cases support its existence) then it is entirely possible that a soil-crop management system that influences sprout exudation will in turn affect the host-pathogen interaction.

B. ARTICULATION.

During this discussion, a number of assumptions were introduced, viz, (1) persistence of the disease (has occurred and) will continue to occur, (2) a set of factors are responsible for disease persistence, (3) knowledge of these factors will lead to development of an economic control, (4) a model for optimum conditions will indicate the ways and means to.factor identification and disease persistence, (5) once the proper combination of conditions is achieved, infection will follow

100 percent wise, (6) a model will permit comparisons to be made between different sets of conditions, chemical treatments and pathogen-host interactions, (7) the acceptance of the concept of suppression will provide a better strategy, (8) suppression is a reality, (9) the sprout will be found to have a characteristic 'envelope' of microbiotas, (10) the microbiota and pathogen interact, (11) a soil-crop management system will influence infection and effect a control.

Since these assumptions are open to experimental proof, it is not possible to quantify them in terms of time. It is not possible to state 'that by January 1978 experimentation will have demonstrated the existence of a link between suppression and microbiota', for example. Thus, in effect, the assumptions must be regarded as hypotheses. It is upon the nature and weight given to the hypotheses that the flow of experimental work will be sustained.

The assumptions stated above can now be grouped into three classes, assumptions 1-3 - persistence, 4-6 - optimization, 7-11 - suppression.

II. FORMULATING OBJECTIVES/GOALS

A. STATEMENT

Under the umbrella of the Branch Objectives and Goals, the Station Goal states that, "By 1982, to identify the factors responsible for the persistence of potato wart disease in Newfoundland, and to develop an economic control". Economic controls can be introduced without knowledge of the persistence-factors. Since immune germ-plasm is used successfully, there is in effect an economic control measure in force. Therefore, it is important to examine the first part of the Goal, since it contains the mandate for the PWDRP. There are two aspects to this, one is that knowledge of the functional roles played in an assumed interaction of host, pathogen and environmental component would create a basis for designing a control program: knowledge of the enemy's strength and weakness is tactically necessary in developing a strategy; the other is that since the situation (of the disease) exists, it is mandatory to learn about the why-fore of persistence because it is a scientific phenomenon.

B. PROGRAM.

The program's objective can be stated as: identification of persistence-factors. This objective is realistic, it represents something that can be done although not necessarily attained at some specified future date. The objective, moreover, conforms very closely to the mandate. It is based on a reasonable expectation of available funds.

The objective is worth the expenditure. The existence of the disease in Newfoundland is in itself something of a phenomenon in North America, being the only known area of persistence and of such widespread distribution (in N America). As the fungus has developed here over the last 6-7 decades, it has been cultivated to the point where speciation in the form of racial forms (biotypes) has taken place. There is, therefore, in the province a very large pool of the organism available for experimental work and a number of biotypes for comparative work. Allied to this is the existence of a mandate for working on the disease which carries with it buildings, equipment, funding and expertise. Proximate to these are new developments for technical research, a ready access to these developments and the peripheral expertise that surrounds these developments. The combination of these factors will (one day) add to the needed knowledge of the potato's number one disease. There are few places in the world where work is carried out on the disease with the potential offered by the Research Station.

Control of Synchytrium endobioticum, the causal agent of the disease, remains a critical need in Newfoundland, and in other potato producing areas in the world. Potato Wart Disease exists in Mexico, Peru, Bolivia, most European Countries, Russia, India, S. Africa and (recently introduced) New Zealand. Many soil and crop management practices favouring potato production have tended to favour the disease, also. Thus, the use of susceptible cultivars, potato monoculture, lack of local quarantines, contaminated seed and cultural implements, and the distribution of susceptible cultivars and disease sources contribute to the inoculum pool and its dispersion. In Newfoundland, where potato producing soils are in critical supply, more than 90% of the coastal villages and 10% of commercial land are infested. The reduction in yield due to S. endobioticum leads to reduced profit, reduced food availability and a waste of irreplaceable fuel resource represented by fertilizer, gasoline, etc.

Approaches to control the disease have been attempted with mixed and often limited success. Chemicals have either not contacted the pathogen or have been phytotoxic; resistant cultivars have 'broken down' to hitherto undiscovered biotypes, etc.; fumigants have provided temporary relief but probably destroy some forms of biological controls. Thus, improved management of natural soil factors, or the creation of opportunities for the function of natural soil factors could offer a unique integrated and natural approach to reducing disease loss without causing undue economic hardship on growers or damage to the environment.

Under this section, reference can be made to previous work on the disease and related current research. Work on Potato Wart Disease has been carried out in infested areas since the turn of the century, particularly in Europe. Chemical control has been tackled vigourously with little success; Plant Breeding has contributed enormously to the problem of control; Ecology has contributed some gross details to our understanding of conducive conditions such as levels of annual precipitation and number of days in the year with temperature lower than a stated figure.

Biochemistry and Physiology have made contributions during the last 15 years as spin-offs from Molecular Biology without throwing much light on events at the parasite - host interface, and many vacuums exist in our understanding of the changes in host physiology induced by infection - likewise, little is known about the host's native defences against Potato Wart Disease. This latter area is strewn with potentially contributing areas, e.g. differences in infectivity of biotypes, superior susceptibility of tomato root tissue of that of potato, the role of auxins and anti-auxins in tumour development, etc. Almost nothing is known about the intimate relationship of host to pathogen in terms of soil physical, chemical and biological components, yet it is precisely in the soil milieu that the events involved in infection ensue - an area that one would have thought of as of high investigational priority. There is a considerable body of literature in descriptive veins but little interpretive analyses.

Research on Potato Wart Disease throughout the world is not extensive. In the period September, 1968 to June, 1976, no more than 59 articles can be cited, of these 19 are descriptive, miscellaneous ones; 7 are devoted to Plant Breeding and resistance testing, 3 deal with extraction and isolation of the pathogen, 14 are of a biochemical/physiological nature, 5 concern chemical control, 9 describe new races and hosts, and 2 deal with ecological influences. The number of research papers published globally/year is 5. Some are of dubious research interest and tend to be more descriptive than interpretive. Of 40 research papers, 31 originate from eastern European countries - Russia is the greatest single contributor, contributing all the biochemical, most of the physiological and half the biotype papers. Almost the sole contributor in the Americas, Newfoundland is a major world contributor (15 descriptive and/or interpretive papers in 4 years). The bulk of the remaining articles originate in Western Europe, with occasional articles from India, New Zealand and Latin America.

The objective specifies what is to be achieved and when it is to be achieved. The objective is not clear on how much is to be achieved. Since there is a great deal of open-endedness to biological research, it is difficult to exactly quantify the objective. The objective does not consider how itself may be achieved. Thus, the objective remains sufficiently flexible so that it can respond to changes that will undoubtedly occur. The timing must be open to question because there is so great an element of serendipity, so great a factor of fortuity in this research. A simple factor of inability to achieve infection can delay the program many months!

Does the objective offer a challenge? As seen from the statement of the objective, there is no mandate on how to achieve the objective. It is in this area that the great challenges lie. Not only are there challenges of techniques to devise to secure bits of information but there are challenges in interpreting the scene correctly to know what bits of information should be sought for. As an example, most of the work is carried out on potatoes, tomato, however, is equally (or more so) infectible. Since beginning survey work on tomato cultivars, every cultivar tested has proven susceptible to the pathogen, as is not the case with individual members of a potato clone. It may prove to be entirely beneficial to pursue the major part of the work with tomato since roots are susceptible, the cultivars respond 100% to the pathogen, it is a quickly maturing plant and can be thickly sown. There are challenges of organization so that parts of the program are not left behind, and parts of the program are contributing to other parts of the program. There are challenges in devising the program, in reducing the mandated objective to a series of mini-objectives that come to fruition in different periods of time.

Referring back to the lists of assumptions, those listed under "persistence" are best taken as given. Those listed in the "optimization" class were referred to as having provided a basis for work which tended to founder on the assumption that 100% infection can be achieved and held. Since 100% infection is rare, and since some infection appears to be the case, the assumptions listed as "suppressive" appear most realistic. Some infection is interpreted as suppression in some instances. Why infection should not take place when all conditions appear to favour it is a more fruitful field, a more generative idea than "optimization". The lack of infection can reasonably be interpreted as a break down in the pathogen-host chain. If it was possible to know the nature of the breakdown, it would be possible to find out just how much to attenuate that link until it breaks. At that point, one has achieved control.

C. <u>PROGRAM-RELATED OBJECTIVES</u>

Since "suppression" appears to be a more realistic approach, there are several objectives to the approach that should be met.

1) <u>To identify and characterize soils that suppress Potato Wart Disease</u>.

A soil is considered "suppressive" if <u>S. endobioticum</u> is established in the soil but will not cause disease in spite of virulent qualities, presence of susceptible host, and presence of apparently favourable environment. Techniques are available for greenhouse and controlled environment room production of the disease, and for testing soils in wart-suppressive qualities. Quantitative assays have been developed for pathogen extraction (sporangia) and thus for identifying and characterizing soils where suppression occurs. These assays are based on a dry-sieving process and propagule (sporangia) - collection on membrane filters, or by a soil-dilution/membrane filter process. An assay has been developed to determine the viability of extractable sporangia. Potato seed can be planted in soils containing various inoculum densities with the resultant relationship between disease severity and inoculum density subject to analysis. Soils can be sought for their suppressive properties to *S. endobioticum*. Soils prepared with different physical characteristics can be amended with different physical and chemical components. Thus unique physical or chemical conditions will be examined through using suppressive soils.

Aqueous extracts of various concentrations will be made for suppressive soils and lab-tested for suppression of sporangia germination. Treatments such as pasteurization will determine whether biotic or abiotic factors are involved. Suppressive soils will be soil-diluted and tested for residual suppressiveness.

2) To determine the mechanism(s) involved in the suppression of S. endobioticum in certain soils, or following crop-management systems.

Information will be contributed by experiments designed to yield data on biotic/abiotic factors responsible for suppression - soil sterilization, pasteurization, sonication, anti-biotic, fungicidal or other selective chemical treatments. It is important to distinguish clearly between direct effects of soil environment on *S. endobioticum* v. effects acting through soil microbiota.

Mechanisms may implicate bacteria, volatiles, root and sprout exudates, organometal complexes, uptake or absorption of active components, binding capacity, binding constraints, nutrient concentrations, groups of micro-organisms, selected micro-organisms, anaerobes and microbial metabolic excretions.

S. endobioticum propagules exist uniformly distributed in 3-dimensional space, it is important to understand this soil space pattern. Experiments need to be designed to seek the influence of this pattern on suppression since the dormant inoculum is apparently activated when a suitable host substrate is available. *S. endobioticum* exists in a host-pathogen relationship in soil as 1) non-motile sporangia distributed about a fixed infection court, and 2) motile zoospores about a fixed infection court. Mathematical models can be generated from this information to demonstrate influence of suppressive factors.

Techniques have been designed for collecting exudates, leachates and extracts, lyophilizing them and characterizing them by chromatographic and centrifugal separation procedures. Their influence on sporangial viability and disease suppression can be assayed.

3) <u>To identify or develop soil-crop management systems suppressive to Potato Wart Disease</u>.

Management is the means by which soil-crop environment can be changed replacing an established niche by a new one, resulting in a microbiological shift detrimental to S. endobioticum. Management can be used to bring about ecological or biological control. Management practices emphasize the influence of soil moisture stress, cropping sequence, tillage, fallowing, rotation, aeration, flooding, ploughing depth, nematode/crop combinations, resistant non-host crops, trap plants, inhibiting plants, irrigation timing, Ca levels, soil properties, root stock-scion combinations, cropping history, fertilizer and irrigation practices, history of pesticide use, combination of factors favourable to disease, organic fertilizers, soil amendments and endomycomlaizae.

4) <u>To apply suppressive principles</u>.

Suppression with a biological base: wart disease - conducive soils to suppressive soils by addition of responsible micro-organism, by adopting appropriate cropping sequence,by introducing purified antagonist on planting stock, using "nurse " crops to multiply antagonists or helping to maintain populations established in soils, or by manipulation of the soil environment to permit multiplication of resident antagonists, or by using any mechanism that has been found to render a soil suppressive.

III. KEY RESULT AREAS

Since a set of objectives has been detailed, it is obvious that each of these contains series of objectives. There are, in fact, then, a hierarchy of objectives, with the Station goal as an umbrella objective. In order to evaluate the objectives in the overall operation of the program, key result areas indicate ongoing success of the objectives.

1. Client satisfaction:- Criterion for evaluation of objective attainment is by meritorious increase in salary (i.e. merit pay).

2. Productivity:- Criterion here is in the number of publications/ year or unit period.

3. Innovation:- The criteria are in the breakthroughs in progress, the novelty of techniques designed to reach the objective, and in the ideas generated regarding the Wart Problem.

4. Resources:- The indicator of attainment is the increase in laboratory and greenhouse (particularly) working areas and increase in manpower, scientist- or technician-wise. A parallel indicator is when the program's labour becomes divided so that, e.g. laboratory and greenhouse work become separate responsibilities.

5. Management development and effectiveness:- The criterion is in increase in staff delegated to the PWDRP.

6. Employee attitude and performance:- Objective attainment is indicated by willingness to carry out the tasks and in the ideas generated in feed-back discussions.

7. Public responsibility:- The first criterion is in maintaining quarantine of the disease to the Greenhouse/Laboratory complex; and the second is in progress towards economic control of disease.

CHAPTER 3

I. MODIFYING POLICIES:

Management's policy towards the PWDRP is to foster an atmosphere conducive to excellence in research on the disease. Management is committed by reason of the overall departmental aim to develop a viable and self-sustaining agricultural industry (based on free trade and international prices). Thus, each province is mandated to a policy of viable self-sustenance. Newfoundland has viable potential for self-sustenance in certain crop areas - potatoes being one. Perhaps were it not for the widespread presence of S. endobioticum potatoes would be themselves more widespread. Potato Wart Disease exists rather as a spectre. Therefore, with a committment to viability and self-sustenance management is also committed to fostering the means to bring the committment to realization. An interesting question arises as to the extent of potato self-sustenance if the disease was not present, or was certain of elimination in, say, 10 years.

The presence of the disease is a two-pronged instrument, on the one side the disease must be controlled and on the other side the causal organism must be eradicated. The presence of the organism in soils - leaving aside the effect on potatoes - affects fundamentally the movement of produce, the commercial interaction inter-provincially, and the employment of inspectors and quarantine agents.

Therefore, not only is management committed to fostering excellence in research, it is also committed to self-sustenance through the eradication of certain agricultural restraints. We must question, then, must these policies be changed in light of foregoing discussions on objectives, or, more accurately, in the light of the new objectives, ~~and~~ are there policies which will hinder or improve performance in the program? There probably are policies which abut directly on to the program but which are not immediately obvious, therefore, little can be said of them. From the vantage point of program designer, the most influential policy is that of committment of man-years and resources to the program. Restraints begin to appear simply in the amount of work that can be fruitfully executed using the presently available resources. Procedures involved in the working program would probably not be altered if the resource committment were to be increased, however, the attainment of objectives would be hastened and there would develop an increased sense of purpose within the unit. A new policy of resource involvement would promote the objectives.

II. DEVISING PROGRAMS FROM ALTERNATIVE STRATEGIES:

The on-going strategy selected is to develop information on suppression of the disease. Different strategies can be conceived. For example, the opposing strategy - referred to in previous discussion - which sought to optimize the disease situation so as to yield information leading to an understanding of how to achieve disease so as to achieve control. Another strategy is to work entirely with agricultural chemicals, devising ways and means of securing control through fungicides - a strategy pursued by earlier workers. Of course, Plant Breeding provides another strategy and this is also being used. An interesting strategy that has had comment in the literature from time to time is to forbid the growing of potatoes so that over a long time period the ground would self-clean. A strategy that has been consistently exploited by eastern European workers is to examine the ecological requirements of the disease with a view to diagnosing geographical locations as potential harbours for the pathogen. Allied to this is a strategy in which infested soil is moved to different locations and examined for self-cleansing. There do not appear to be any biochemical strategies that would lead to the mandated objective; there are, though, a number of lesser strategies that would yield desirable information in the sense of "know thine enemy". For example, eastern European workers have dwelt much on the development of a straight-forward biochemical test to differentiate between potentially susceptible and potentially immune potato cultivars. The ability to produce infested sprouts in vitro, or growing infected callus tissue are techniques that could open new areas of investigation. Likewise, the altered translocation patterns due to infection and subsequent tumour formation would yield interesting information on the reaction of the plant in the host-pathogen interacting complex, as would information on the growth hormone patterns in the tumour and surrounding tissues.

An attractive strategy that may be very fruitful is to contract out a section of program work to a University department, or co-operate with University departments on a loose basis, with graduate students successively tackling 'bits' of the program. Any strategy that would increase the resources and man-years of the PWDRP would fit nicely with the mandate.

An alternative strategy would be to pursue work on the organism, and on some infectivity conditions through the use of alternative hosts. Although alternative hosts are not generally infected under natural conditions, there are a considerable number of Solanaceous spp. that can be infected under experimental conditions. Chief amongst these is tomato - long known as an alternative host.

There are a number of questions to be considered in analyzing the viability of programs devised from alternative strategies. An examination of these questions will quickly reveal that a number of the above strategies may not be entirely alternative to the one chosen. The first question is whether the strategy will go beyond the mandate, whether it will help to reach a main objective, and whether it is or is not consistent with the

Branch/Station policies. Then, the strategy can be questioned as to whether it will be viable in terms of assumptions about the future, and takes into account internal/external factors. And finally, one can ask whether or not the strategy would involve a feasible form of structural reorganization, require a high degree of co-ordination, require a heavy, long-term committment of resources, and involve a high degree of risk. (The analysis is included as an Appendix).

III. ESTABLISHING PRIORITIES, SCHEDULING AND MONITORING.

A. PRIORITIES

The PWDRP is composed of a number of projects. Two projects have been formally advanced: 1) 31.104.46, "Infectivity parameters of potato wart disease"; 2) 31.104.47, "Germinative responses of potato wart resting sporangium to applied chemical stimulants". Within these projected areas of research, there are numerous sub-projects. Since the project titles are guides to the work, and since, in fact both projects are carried out contemporaneously, and as information from one tends to be used to assist the other, what we are discussing in terms of projects are the sub-projects. Putting the formal projects into simpler terms, "Infectivity" relates to information gained from inoculation and disease situations, "Germination" relates to knowledge about the causal agent.

1. ANALYSIS

Four working concepts have been referred to under the suppression-umbrella. It is necessary to devise a flow of work based on these concepts. Each concept is subject to 4 selected criteria: its relation to the mandate, the knowledge it yields, its dependence of the other concepts, and the resources available for the actual work.

a. MANDATE:- This is the most relevant criterion for judgement. Which task is most central to the mandate? The Branch Goal mandates that work be carried out on improved management practices, and the Station Goal resolves this into 1) identifying developmental factors and 2) economic control method development. Therefore, the 'application of suppressive principles' is most closely allied to the MANDATE the 'mechanism' and 'soil-crop management system identification' concepts are less related.

b. KNOWLEDGE:- This is felt to be the next most relevant criterion. It is obvious, though, that certain pieces of knowledge must be obtained before the improved-management goal can be realized. Closely connected to the criterion of KNOWLEDGE, therefore, is that of DEPENDENCE. The pursuance of 'application of suppressive principles' follows the 'identification of a soil-crop management system'.

In a sense, 'identification of the soil-crop management system' is a small version of the 'application' concept, or conversely 'application' is the institution of the 'soil-crop management system' as a working practice. This is not to say that 'application' in itself would be a problem-free area, but that the real goal is the attainment of a 'soil-crop management system.' To be of any use, it must have general application.

In order to identify the 'soil-crop management system', it is necessary to construct, or build-up, a system. This is done from the blocks of KNOWLEDGE obtained from considering the 'mechanism' of suppression. The identification of a suppressive soil in the first place only serves as a jumping-off place to get at the mechanisms of suppression. But the task of suppressive soil identification must precede that of mechanism-searching.

c. RESOURCES:- The fourth criterion of priority is that of tools, methods, materials - resources. KNOWLEDGE is also a resource, hence equipment is emphasized under RESOURCE heading. This criterion, perhaps, is of more importance in considering the flow of priorities within any one of the working concepts.

2. SUMMARY

It is clear, then, that the stages of suppressive-soil work as laid out under Program-Related Objectives follow a logic dictated by their relationships to mandate, knowledge and resources. The guiding criterion is that of knowledge, since the object of a research program is to obtain (discover) knowledge and to make known the unknown. The knowledge is obtained in bits and is used to build, brick-wise; the secondary object of the research program is to put the bits of knowledge into building the management practices. Although the demands of the mandate urge that identification and application of a soil-crop management system is top priority, in the logic of developing the objective top priority must be given to developing mechanistic principles first.

3. TASKS IN MECHANISM

Two criteria are used to develop a flow of priorities within the exploration of the concept of 'mechanism' - knowledge (/experience) and resources. As much as possible knowledge will be allowed to dominate since resources will be assumed to be non-limiting. Only two vital renewable resources are involved (potato tubers and potato warts) that require special attention and methods of cultivation and storage. All other resources are present or are available on request (subject to budget considerations).

a. IRRIGATION:- Since (wart) galls need to be resourced, they are produced in greenhouse bench soils. This requirement has generated a project on irrigation. All factors that can be are made non-limiting except watering which is applied differentially. Galls are produced and information is gained on behaviour of the disease under different watering regimes. Once the regimes have been built up to optimum, the pattern so used will be retained. Thus lessens the work load, since irrigation differentials must be carefully administered whilst being applied. The watering regime knowledge is thus applicable to the development of pot work.

b. INOCULUM DENSITY:- Likewise, since suppression may be a function not only of water availability, it may be a function of the distribution of sporangia about an infection court. It is necessary to know the limitations imposed by propagule distribution, since the knowledge contributes to mechanism - understanding and also to designing pot work.

c. ADDITIONAL HOSTS:- Tomato tissue is susceptible to *S. endobioticum*. Analysis of tomato tissues c.f. potato tissues will yield information on mechanism, as will the contents and biological activity of exudates from tomato tissues. Other Solanaceous hosts may be used to c.f.

with tomato. Sporangial numbers and age will be used on tomato tissue itself of different ages to obtain a picture of tomato reaction to <u>S. endobioticum</u>.

d. TEMPERATURE:- The influence of temperature levels on disease and resting sporangia will be looked at. Temperature influences propagules before inoculation, during inoculation and subsequent disease development.

e. SPROUT EXUDATES:- The discovery of a large ninhydrin-positive efflux from potato sprouts predicates much biological activity about the sprout. This activity should perhaps be accorded high investigational priority, since it may be directly responsible for suppression.

f. FUNGICIDAL TREATMENT:- This task has been completed. In a sense the observation that Potato Wart Disease was greater under fungicidal influence suggested the existence of a normally suppressive field measure.

g. MICRO-ORGANISMS:- This is a logical follow-through from sprout exudates. Field soils can be analyzed for the presence of influential micro-organisms, and micro-organisms can be added to soil to determine their role in suppression.

h. PASTEURIZATION:- Pasteurizing, or heat treating soils should precede micro-organism work to demonstrate an abiotic or biotic suppressive factor.

i. SONICATION:- This is another technique to be used on field soil to differentiate between abiotic vs. biotic influences.

j. STERILIZATION:- This is also a technique to determine if the factor is biotic or not.

k. SOIL TREATMENTS:- Amending soils with chemicals to either simulate chemical factors or to enhance or select micro-organism growth will also yield information on the biotic factor. An example that has been used is to amend soil with chitin to encourage the growth of chitin-consumers - S. endobioticum contains chitin as a wall component, and not cellulose.

l. BINDING:- Chemicals can be used to demonstrate whether S. endobioticum is suppressed (or enhanced) by binding to soil particles and/or infection courts. The observation that cationic fluorochromes react in sporangial tissues, as opposed to anionic which do not, and are susceptible to pH levels - i.e. fluorescence is a function of ionic dissociation suggesting that electrostatic charging may be an influential factor.

m. DILUTION:- This technique is to determine the limits of a suppressive factor.

4. MECHANISM TASK PRIORITIES

Work is already being pursued on IRRIGATION and INOCULUM DENSITY (SPORANGIAL NUMBERS). The knowledge is needed to complete other tasks, and since they are on-going, easy to complete. After completion of these tasks, the next piece of information needed is to determine whether the suppressive factor is biotic or abiotic. Heat treatments such as PASTEURIZATION and STERILIZATION will be applied; also SONICATION. DILUTION will also provide information on the presence of volatiles or other physical agent in a natural field soil. When the direction biotic or abiotic is determined, work will move to a closer examination of a physical principle, if biotic. If biotic, TEMPERATURE, DILUTION, BINDING and SOIL TREATMENTS will be examined. The influence of SPROUT EXUDATES will follow the accumulation of information from other areas. Thus, priorities are developed on the criteria of ease of completion, knowledge needed and dependence.

5. TASKS IN SOIL-CROP MANAGEMENT SYSTEMS AND IN APPLICATION OF SUPPRESSIVE PRINCIPLES

At this point it becomes extremely difficult to develop any definite planning, since it is necessary to develop the information potentially yieldable by examining mechanistic principles in suppression of Potato Wart Disease. On the basis of that information, the systems and their application can be built.

B. SCHEDULING

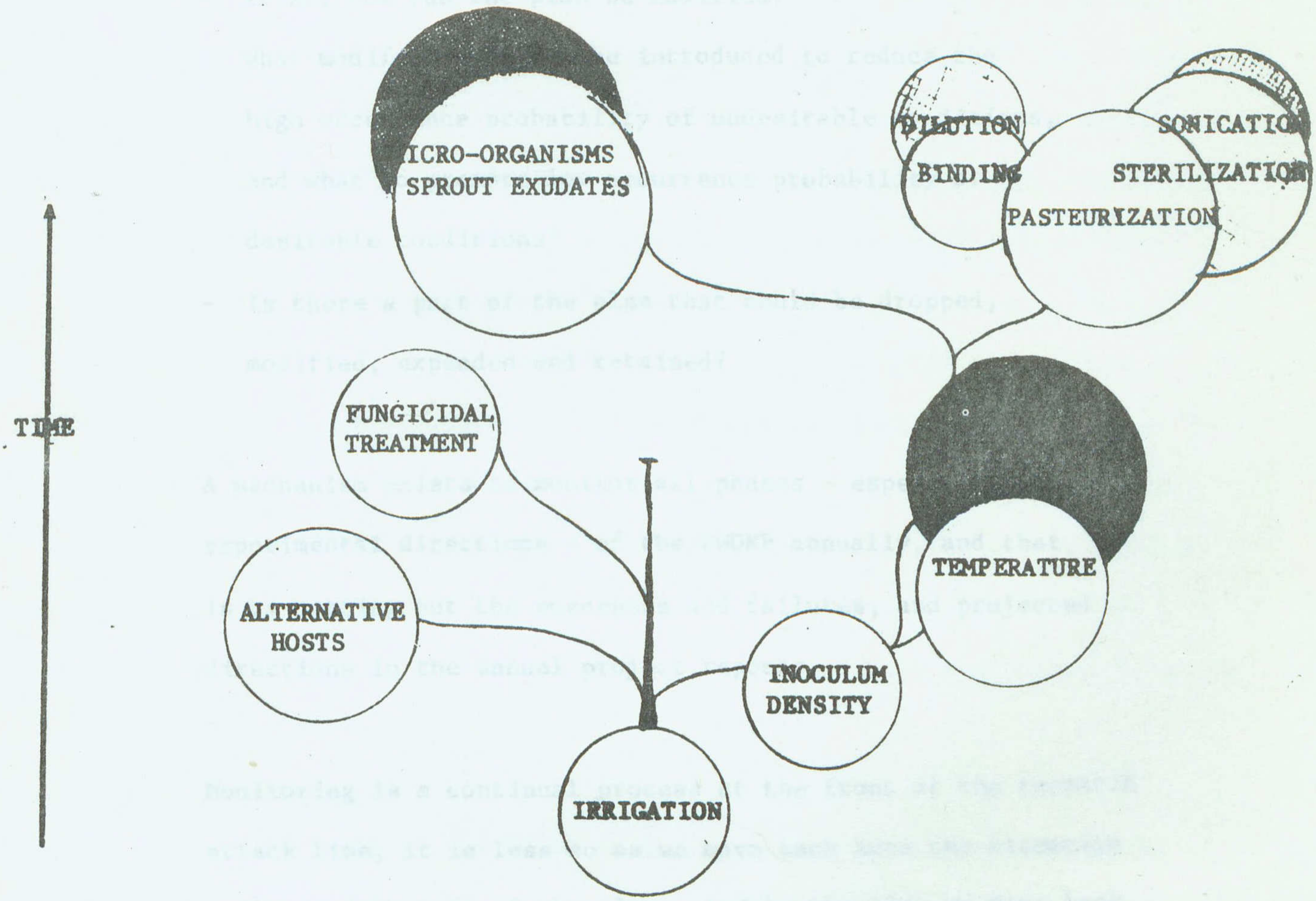
1. SCHEDULING PRINCIPLES

It is clear that mechanistic principles must be sought and identified prior to engaging in the developing of a soil-crop system, hence the scheduling amongst the major tasks is self-evident. Scheduling within the area of mechanism, however, must be closely detailed. At best, it can only be a guide to work done because living materials do not work like machines and are subject to a great number of vagaries, some of which may be uncontrollable. S. endobioticum itself is an organism with apparently more than a customary share of fickleness and capriciousness.

It is difficult to put time limits on the experimental work, 1) a happy discovery may eliminate or short-cut scheduled work, 2) conversely, the work may need to be duplicated or lengthened, 3) it is not known how long some processes take. Thus, we can state that we will run a viability test for 10 weeks, this will "tie up" a block of time, but we do not know how many times we may have to run that 10 week test. Nor do we know how many basic components a given task, such as inoculating by carrying propagules on filter discs, must be broken down to, such as the size of the disc, the kind of disc, the purification of the disc, etc. Likewise, a new task will take proportionately more time to complete cf. with a well routined task, and as time goes on the task time will shorten through familiarity.

2. SCHEDULING NETWORK

The simplest approach to scheduling the work is to develop a tree. The priorities (detailed under MECHANISTIC PRINCIPLES) lie along the tree thus:



C. MONITORING

The following questions arise as a result of monitoring the PWDRP:

- Need the original projection change in the light of current findings?
- If so, how can the plan be modified?
- What modifications can be introduced to reduce the high occurrence probability of undesirable conditions, and what to promote low occurrence probability of desirable conditions?
- Is there a part of the plan that could be dropped, modified, expanded and retained?

A mechanism exists to monitor all phases - especially the experimental directions - of the PWDRP annually, and that is by setting out the successes and failures, and projected directions in the annual project reports.

Monitoring is a continual process at the front of the research attack line, it is less so as we move back into the situation analysis (phase I) of the plan. And by the time we move back to the mandate even less monitoring occurs. Thus, modifications may take place with the mandate every 5 years or less - the modification depending on the nature of the research front findings and their applications. Thus, the mandate varies less than any other factor but once changed its influence now feeds back along the line to mediate the frontal action again. Therefore, monitoring is a to - and - fro's effort between the mandate and the actual work effort.

It is in the front research area that day-to-day and week to week monitoring occurs. As an example, it has become obvious, through this present analysis, that the accumulation of results will be speeded up by adopting a more concentrated work strategy - by spending a certain percentage of the week on a sub-task (since the overall work demands certain percentages of time) we have achieved a strategy of "result-dilution". That strategy was originally adopted so that at the annual monitoring exercise one could state, within the percentages allocated to projects and sub-projects, results pertinent to each allocated work area. Monitoring of the tasks on a daily basis with the various phases, goals, objectives, etc. of the PWDRP in mind has exposed the strategy of working-to-completion one sub-task area before entering another.

Monitoring in the PWDRP is not much of a paper task, but it is very much a mental one. Setting out the broad outlines of priorities of a project in a schedule network strategically places the research work in a constant review position.

As the planning procedure developed herein is informal, evaluation of all phases takes place constantly through consideration of the significance of the results achieved, and how the results can be built back into the program. In other words, the PWDRP is a self-generating program, moving forward on the results of its own uncovering. Our task is to keep it guided through the most germinative and fruitful direction, and take care that its momentum is maintained. This is done through continual monitoring.

APPENDIX

B. IRRIGATION

1. Aim

The aim of this sub-project is to examine the influence of watering frequency on development of potato wart disease. A parallel aim is to determine, under the "optimization" strategy, the optimum regime for watering to produce the most amount of the disease.

2. Origin

The sub-project began as an offshoot of the need to grow potato plants in infested soil to produce wart as inoculum, since the parasite is obligate and must be cultured *in vivo*. To extend what was already an ongoing task, complete with soil benches, greenhouse, etc., irrigation hose was laid out along the bench, tubers planted at the loci where water spouts fell to the soil, and inoculated *in situ*.

3. Tasks

a) Scheme I. -

The first task is to plant out a bench and irrigate for one week at 1½ h. daily. The following month a second bench is set up and watered at 1½ h/d for two weeks, likewise a month later a third bench is watered for three weeks. At the commencement of the fourth month the first bench is planted again and subject to one week irrigation. So the system is continued throughout the benches month by month.

b) Scheme II. -

Next, each bench is subdivided by 3, and each section received 1, 2 or 3 wk water. In this system, in the following month the second bench also is watered according to the differential regime.

c) Scheme III. -

One bench is irrigated tri-partitely so that the first section received water for 3 wk, the second for the next 3 wk, and the third for the last 3 wk.

d) Scheme IV. -

One bench is irrigated tri-partitely so that within the first 3 wk period, one section was watered daily, the next section every 2 d, and the last section every 3-4 d.

e) Scheme V. -

Using two benches, each on alternate months, the bench is tri-partitely watered so that over the first 2 wk, the first section is watered for ½ h/d, the second 1 h/d and the third 1½ h/d.

f) Scheme VI. -

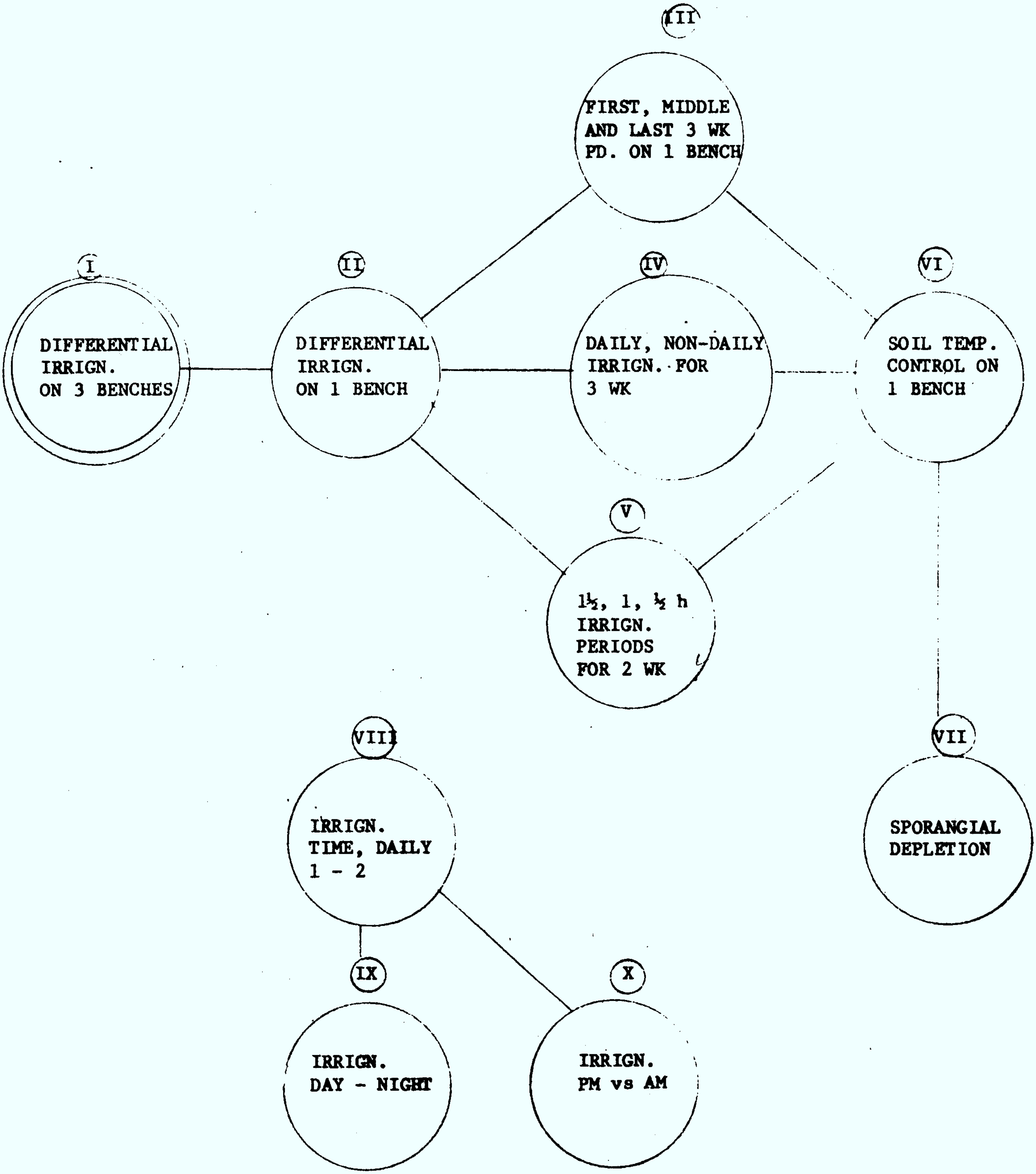
Since there is no temperature control in these benches, save that of modifying air temp. by ventilation, and some soil temp. through the application of less-than-ambient-temperature water, a further bench is set up with a refrigeration coil spaced across its plane at the base.

j) Scheme X. -

The function of this scheme is to determine the distance in time apart of two daily applications.

4. Influence Diagram

These schemes are presented in the accompanying influence diagram, with a suggested sequence. Since the results can be skewed by influence of season and/or sporangial behaviour vis-à-vis season, each scheme is carried out for no less than nine months. This is dependent on host and pathogen supply. This means, normally, Dec./Jan. - Sept./Oct.


III
FIRST, MIDDLE AND LAST 3 WK PD. ON 1 BENCH
I
DIFFERENTIAL IRRIGN. ON 3 BENCHES
II
DIFFERENTIAL IRRIGN. ON 1 BENCH
IV
DAILY, NON-DAILY IRRIGN. FOR 3 WK
VI
SOIL TEMP. CONTROL ON 1 BENCH
V
1½, 1, ½ h IRRIGN. PERIODS FOR 2 WK
VIII
IRRIGN. TIME, DAILY 1 - 2
VII
SPORANGIAL DEPLETION
IX
IRRIGN. DAY - NIGHT
X
IRRIGN. PM vs AM

C. ADDITIONAL HOSTS

1. Aim

Besides Solanum tuberosum, the common white potato, other Solanaceous genera contain members which, under experimental conditions, have been shown to act as hosts to the potato wart disease pathogen. Since 'tomatoes' constitute an actual local industry, with potential for growth, some information on the susceptibility of tomato cultivars to the widespread pathogen is necessary.

2. Origin

From the thrust of seeking information on cultivar susceptibility has developed a sub-project that is concerned more specifically with the biology/ecology of the pathogen, vis-à-vis tomato and other susceptible Solanaceae. It is quite possibly that either an additional species or a tomato cultivar can serve admirably as an assay organism for the PWDRP. Tomato seeds, for example, are easily obtained, easily stored and germinated, easily transplanted, cultured and inoculated. They can be sown in large numbers, mature quickly, handle easily and require small space. Through their use, it is possible to achieve large statistical numbers of infected plants and to achieve a rapid turn-over rate of experimentation. Potato/wart disease fungus complex does not possess many of these features.

Therefore, the sub-project is being expanded to account for experimentation.

3. Tasks

a) Cultivar Testing:- This satisfies the original projected thrust. All commercially available cultivars are inoculated. These are checked after 4 weeks post-inoculation for sporangia and rated at Low, Medium or High indices of infection.

b) Genera Testing:- The other Solanaceous genera are tested in like manner.

c) Inoculation Method:- These seedlings are inoculated by adding pieces of wart to the base of seedling stems, growing in sporangial infested mix, or by dragging the root system through a slurry of sporangia.

d) Irrigation Method:- The seedlings, in pots, are watered either from the top, to field capacity, or are stood in water taken up, then, by capillary action. The actual influence of watering on disease expression is further explored by watering to different levels of field capacity over different periods of time.

e) Inoculum Density:- A cultivar is planted out in mix of different levels of infestation, or inoculated through slurries of different sporangial concentrations. The reaction of different cultivars and different Solanaceous genera to different levels of sporangia are also examined.

f) Time After Inoculation:- The standard adopted is 4 weeks. Cultivar is inoculated and read for sporangial numbers every 1, 2, 3 or 7 days for 28 days.

g) Cultivar Confirmation:- Following the acquisition of new information derived from these experiments, selected cultivars are re-checked for the accuracy of the original indices of infection.

h) Maturity:- Extending the observation period for tomato, etc. cultivars: the standard observation period is 4 weeks, before the plant becomes too big and difficult to examine satisfactorily. Cultivars are grown in infested situations until the fruit is produced.

i) Temperature:- Along with watering and inoculum density, temperature is an important parameter to examine. Seedlings are grown in infested soil/or slurried and planted, and the pots set in a soil bench in which a refrigeration coil controls ambient soil temperature.

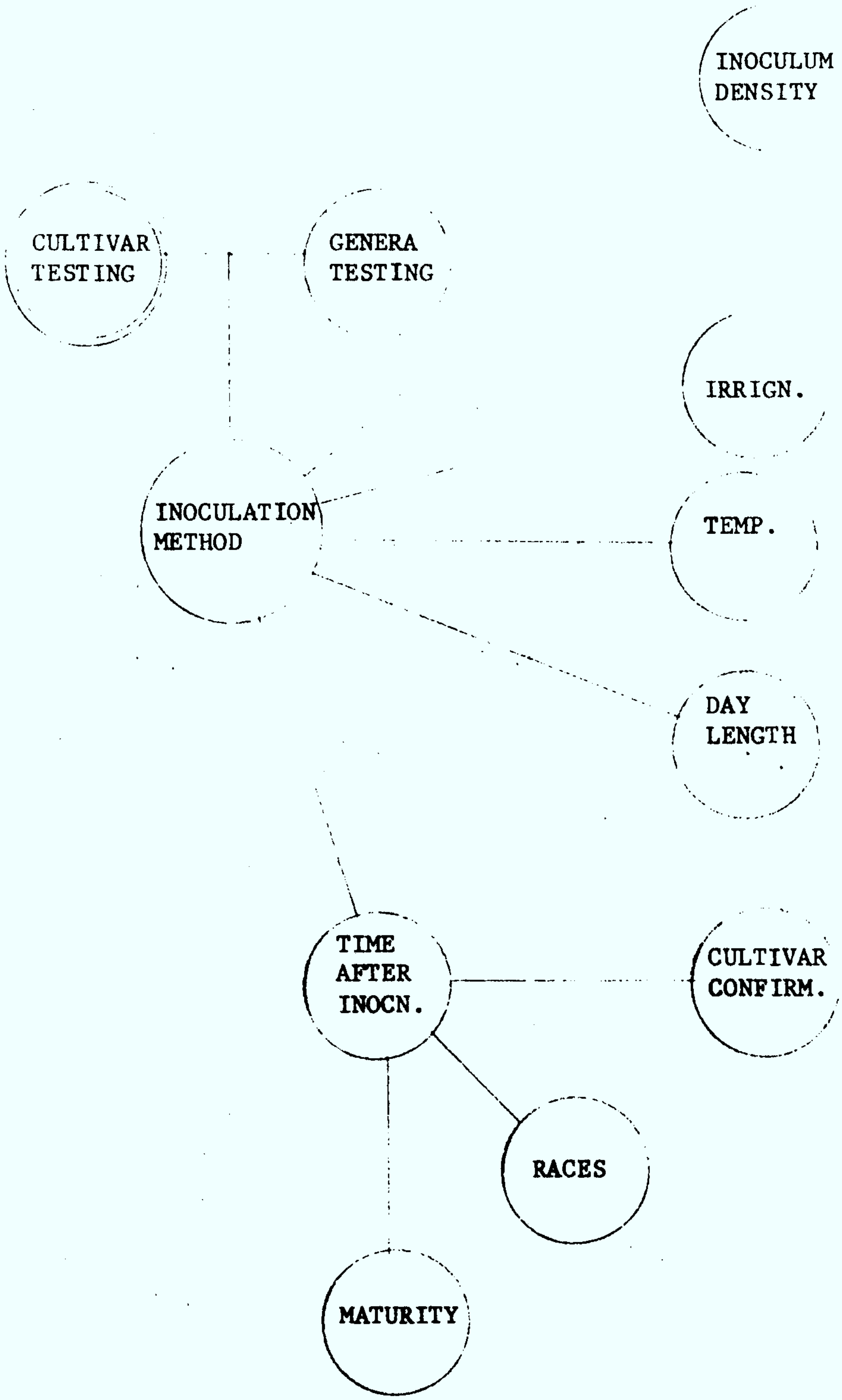
j) Races:- The reaction of cultivars to different races of potato wart disease pathogen is checked out through the standard inoculation conditions. In here may lie a quick method to differentiating between races in infested soil. If there is, sufficient justification for the additional host work is apparent.

k) Day Length:- This is a cultural parameter that is examined along with temperature and water, etc.

4. Influence Diagram

This work is best carried out after the "potato season", when the current supply of tubers are spent, and dormancy exists among the new harvest.

INFLUENCE DIAGRAM - ADDITIONAL HOSTS



D. INOCULUM DENSITY

1. Aim

Inoculum density, or critical levels of propagules (in this case resting sporangia or summer sporangia), is a key information area in the PWDRP. It is necessary to know limits to infection imposed by sporangial levels and sporangial distribution. The distribution of sporangia in soil is a clue to the intensity of disease expression, to the percent infection, to the design of pot work, to an understanding of numerous influences impinging on the interface - fungus:sprout, and to the understanding of the mechanics of disease suppression (or disease enhancement). The aim is to develop a quantity of information so that a model can be constructed (albeit mental) of the situation regarding the distribution of sporangia in the soil medium, their relation to each other, their relation to the sprout, and their relation to the mechanism of disease suppression.

2. Previous Work

Using a potting mix infested with pieces of wart, or dried crushed wart, or separated sporangia, or putting wart pieces proximate to sprouts, tubers have been inoculated. In some of this work, the sporangia were either calculated for number from the crushed wart, calculated for number from separated sporangia, or counted from a suspension held on a filter disc. Little influence could be discerned of the effect of number (more influence appeared to be attributable to sporangial age). However, some experiments were carried out in which massive numbers of sporangia were used without infection occurring.

3. <u>Work Strategy</u>

It is extremely difficult to reduce the inoculation event to less than several parameters. There will also always be variations since any repetition of an experiment can never be exactly a duplicate. And, since each experiment is immediately a combination of factors, it is difficult to process a linear series of experiments or a working plan built on the principle of dichotomy. It may at first thought seem to be a relatively simple matter to continue to vary the sporangial numbers and arrive at a <u>number vs. infection</u> situation. But in any one experiment, the following factors operate: sporangial number, sporangial age, sporangial treatment, form of sporangia, state of inoculum, method of applying inoculum, mode of watering, contact time of sporangia (inoculum) and sprout, age of sprout, size of sprout, number of sprout, age of tuber, treatment of tuber, temperature of inoculation, temperature of development, sporangial antagonists, zoospore predators, soil type, soil amendment, pH of soil, day length, race of pathogen.

Since so many factors, and others such as soil O_2/CO_2 levels, etc., impinge on the critical event, the approach is to abandon a linear strategy and continue to set up inoculation experiments carefully recording measurablc data, and varying components at random. In this way, a picture will develop which will serve to function as a hypothesis of sprout:fungus interface reaction.

4. Tasks

a) inoculation:-

i. Techniques

A number of techniques have been developed for inoculating potato tuber sprouts. These utilize fresh or dry wart. Pieces of wart, per se, are not useful quantitative units for determining critical levels for sporangia. The techniques have been developed for the purpose of establishing the reactions of tubers - or cultivars - to the fungus - or race - in order to determine levels of resistance in conjunction with breeding programmes. As far as the experimenter is concerned, what is required is a technique that allows numbers of sporangia to be readily varied, is simple and easy to carry out and maintain, and will lend itself to reproducible result production. A brief discussion of the techniques follows.

- SPIECKERMAN AND KOTTHOF. Originating in 1924, this technique involves placing wart compost on eyes, enough to cover a dime. Inoculated tuber-pieces were then covered with sand and kept moist.

- GLYNNE. From 1925, fresh wart pieces were pinned next to sprouts. The tubers were covered with paper and kept in a moist state.

- LEMMERZAHL. From 1930, vaseline rings were made around sprouts. Wart slices were suspended in water around sprouts, and tubers kept in a moisture chamber.

- GLYNNE-LEMMERZAHL. Published in 1963, and widely used, wart slices were suspended in water and after an incubation period in a damp atmosphere, tubers were covered with disinfected wet peat.

- MODIFIED GLYNNE-LEMMERZAHL. More recently, 1976, a modification was published in which 1) water was replaced daily, 2) damp cotton wool (sic) was used instead of peat moss.

- THIEDE AND WIERLING. 1960, a technique in which wart compost (wart + sand) was scattered over tuber pieces, and the tubers covered with paper towel and kept wet.

- DIEHL. In 1962, a significantly different technique was published in which a glass tube was screwed around a sprout and wart pieces were suspended in water around the sprout.

- MODIFIED DIEHL. In our work we adapted Diehl's technique - sporangia were deposited on filter discs and placed in the water column.

- MODIFIED GLYNNE. We have also adapted Glynne's technique by draping sporangial discs over sprouts.

ii. Approaches

There are other details such as temperature and contact time. There are three approaches to inoculation (use of inoculum), 1) compost, 2) fresh wart slices, 3) extracted and separated sporangia. Since the number of sporangia are very variable among wart slices, extracted and separated sporangia give the only real measurement of sporangial number. Separating sporangia, however, may be a deleterious tactic because the normally attached wart tissue may have a role to play in the germination (hence infectivity, pathogenicity or virulence) of the fungus. Another complication to the inoculation method is that some of the techniques only allow the inoculum to be in contact with the host tissues for a short period of time, and are not intended for tubers to be buried with inoculum until harvest-time 8^+ weeks later.

b) Sporangial Number:-

This is difficult to dissociate from sporangial age, since in nearly all cases each inoculum is unique and of a different age. Through the mediation of the above techniques, sporangial numbers can be varied infinitely.

c) Sporangial Age:-

On the other hand, large differences in age can be contrasted sufficiently with no. to provide information on their differential roles. Sporangia extracted from fresh wart contain larger percentage of summer sporangia, and are often found to be of high infectivity, 2 mo. old have a lowered virulence, 4 mo. old are more infective. Therefore, does twice the number of 2-mo. old sporangia produce the same level of disease as a unit number of young sporangia?

d) Contact Time:-

Does the length of time that sporangia are in close physical association with the sprout affect the outcome of the disease situation. Does half the number of sporangia require twice the time?

e) Sprout Age:-

Most experimenters prefer to use sprouts that are 2 mm long. Does the age of the sprout influence this usage? Does the age relate to the numbers of proximate sporangia?

f) Sprout Length:-

Is the whole sprout infectible, or is there a particularly susceptible area? Does sporangial number relate to the need to provide a statistical certainty for ensuring that a critical level of sporangia are present at the precise sprout area at the right time?

g) Sprout No.:-

How relevant is this to sporangial no.?

h) Temperature:-

Not only over what range does infection take place, but is temperature limiting, and is effect overcome by increasing sporangial number?

i) Moisture:-

The incidence of disease is also dependent on moisture levels, as the zoospores need a liquid medium for movement. To determine an exact relation between sporangial no. and ambient moisture a scheme is devised to inoculate and grow plants at % of field capacity. Using a rapidly growing plant such as potato presents several problems since the watering intervals (dependant on weight changes) change quickly as the transpiring mass grows.

j) Day Length:-

A repetition of the disease cycle under different growth-room mediated light conditions.

k) Tuber Age:-

Tubers stored over time change in chemical content, C:N ratios change, as do sugar:starch ratios. Do older tubers require a higher number of sporangia for infection?

l) Soil Type:-

The role of soil type is fundamental. The structure, porosity, etc. physical factors, all play parts in the pathogen-host interaction. Soil types can be constructed to yield a variety of obstacles to zoospore migration. Does sporangial mass overcome the limitations imposed by soil structure? Are some soil structures more or less suppressive to infection, and disease expression?

m) Soil Amendments:-

This task is to account for already-present soil features, impossible to dissociate from the presentation of a soil interface to sporangium, zoospore and sprout, and for features that can be modified or added to or incorporated manually. There are a great many soil features which are influential on the pathogen:host relationship. Some are physical, such as pH, base-exchange, O_2/CO_2 and O_2/C_2H_4 ratios, others are chemical such as NH_4-N, NO_3-N, root exudates, sprout exudates, etc.

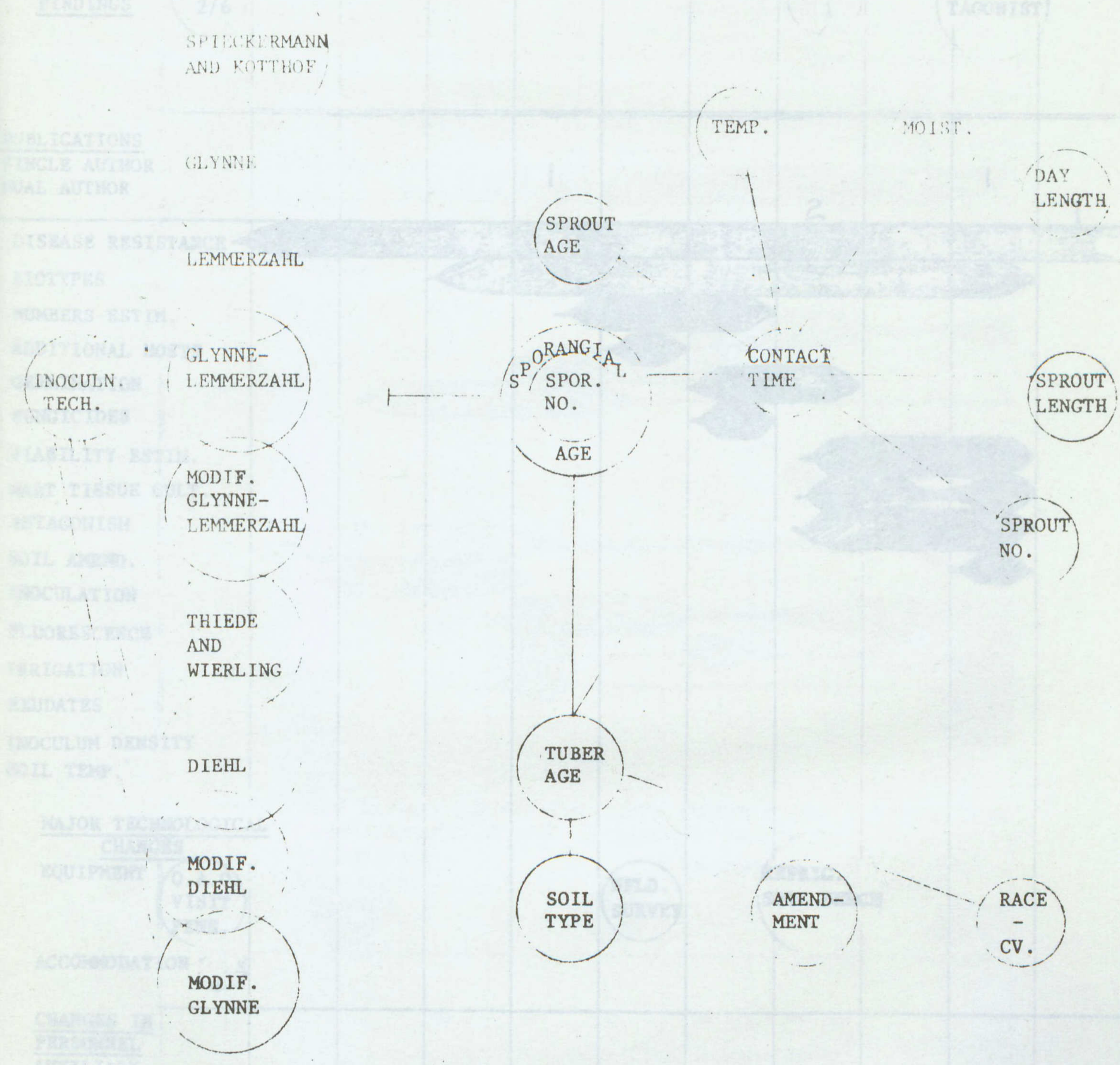
n) Race/Cultivar:-

The work takes on an added dimension by using different races and, concomitantly, different cultivars.

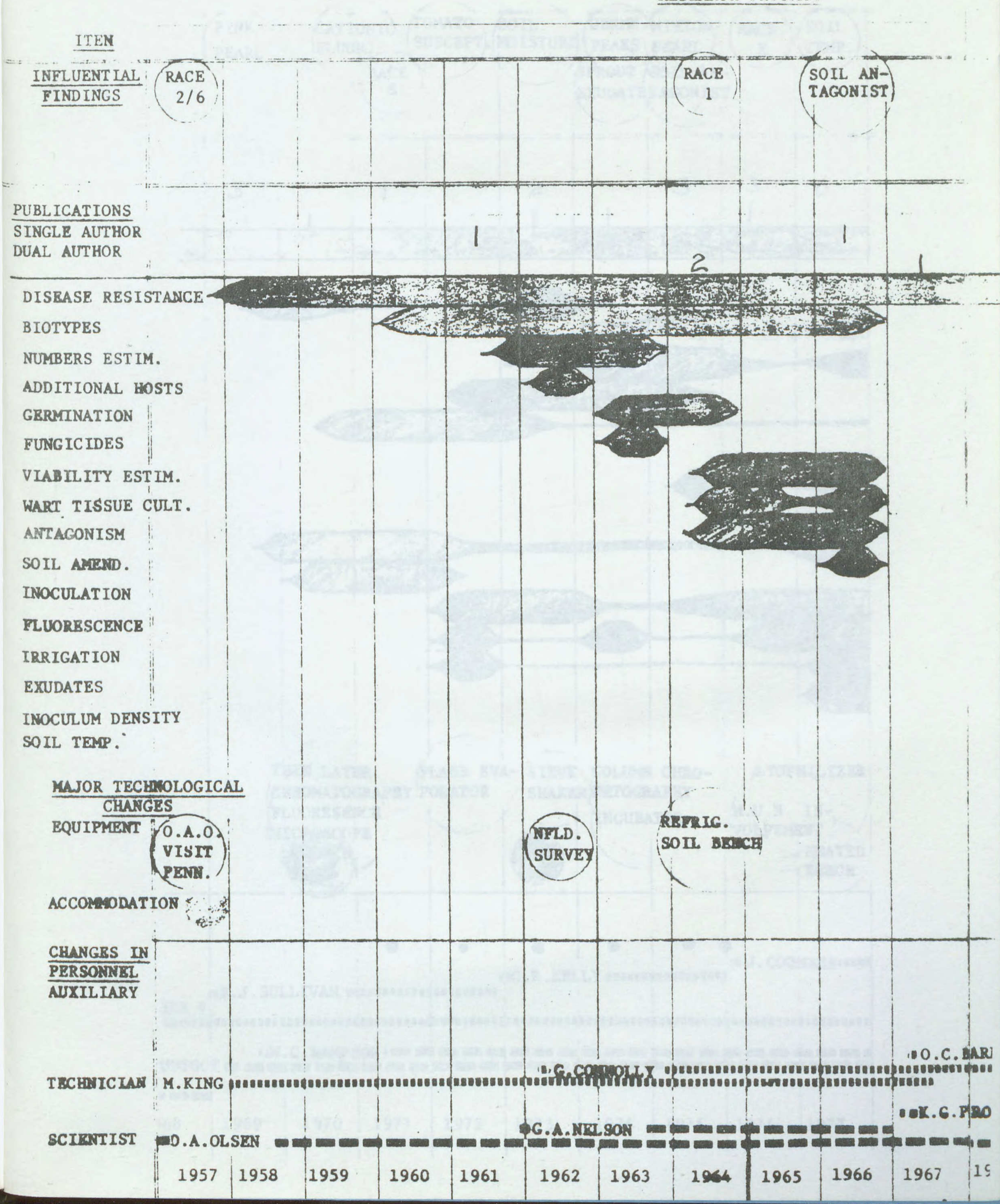
5. Influence Diagram

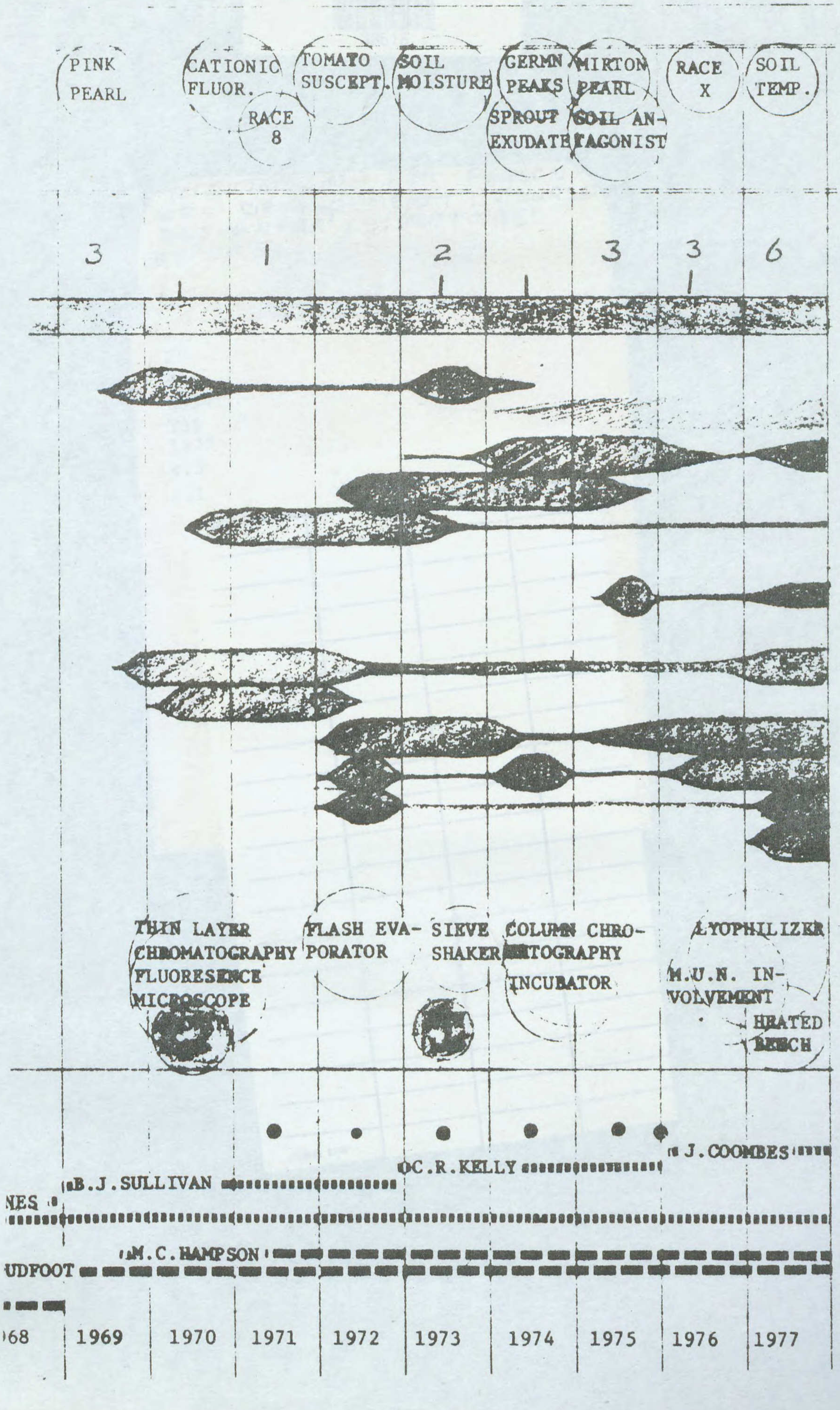
These tasks are displayed in time and content-relation in the following diagram.

INFLUENCE DIAGRAM - INOCULUM DENSITY



CONTEXTURAL MAP OF ... RESEARCH PROGRAM




PINK PEARL
CATIONIC FLUOR.
RACE 8
TOMATO SUSCEPT.
SOIL MOISTURE
GERMN PEAKS
SPROUT EXUDATE
MIRTON PEARL
SOIL ANTAGONIST
RACE X
SOIL TEMP.
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3
3
6
THIN LAYER CHROMATOGRAPHY
FLUORESENCE MICROSCOPE
FLASH EVAPORATOR
SIEVE SHAKER
COLUMN CHROMATOGRAPHY
INCUBATOR
LYOPHILIZER
M.U.N. INVOLVEMENT
HEATED BENCH
J.COOMBES
C.R.KELLY
B.J.SULLIVAN
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TELE-TRAINING FOR PERSON-NEL DEVELOPMENT: COURSE DESIGNERS'/DIRECTORS' REPORT.

Date Due
