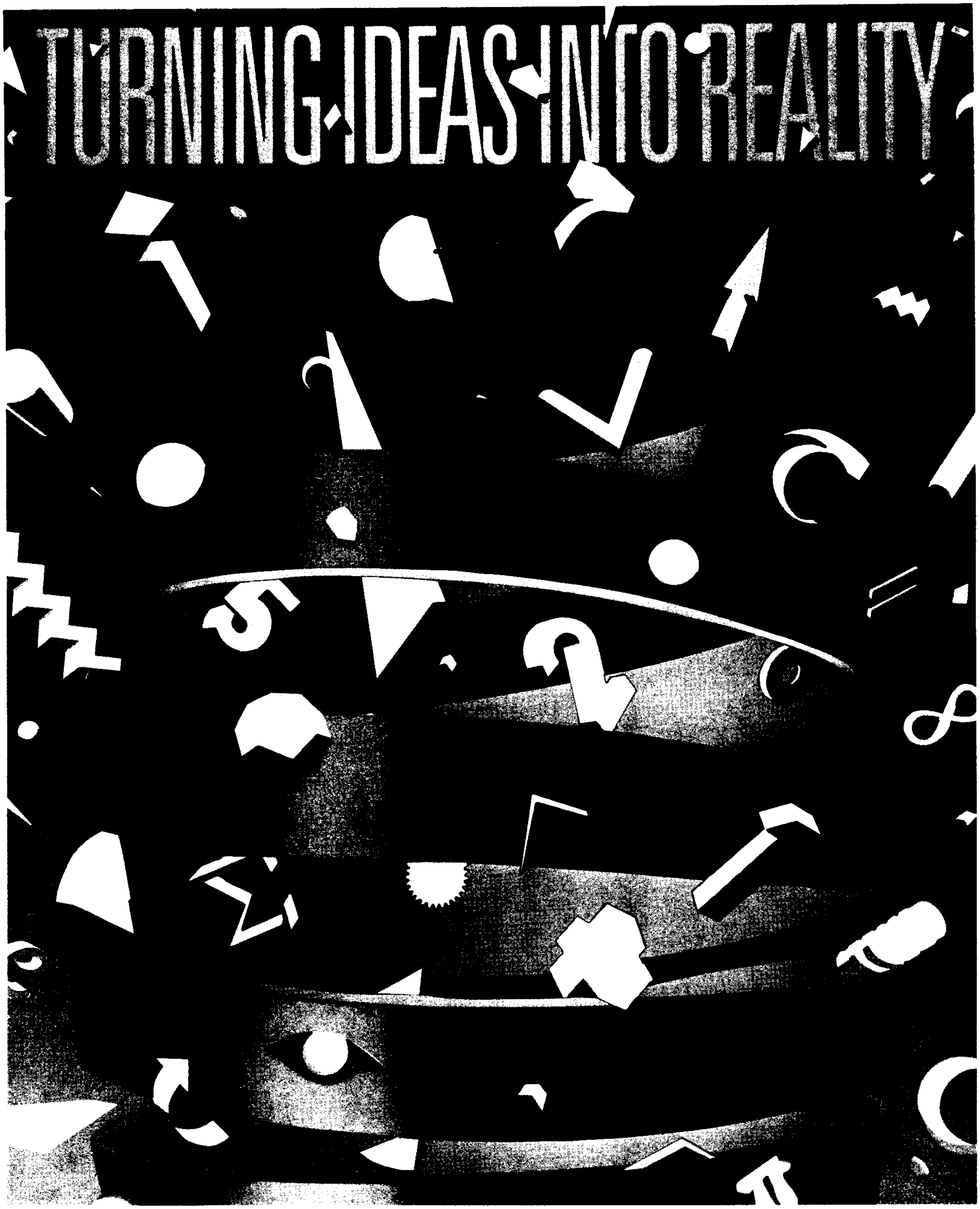
THE
NORTHERN ENGINEER



National Engineers Week February 21-27, 1988

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Spring 1987

EDITORIAL

by

Vincent S. Haneman, Jr., Dean, P.E.
School of Engineering

The direction of this issue of *The Northern Engineer* is well-described by the 1988 Engineer's Week slogan, "Turning Ideas into Reality." The use of the National Society of Professional Engineers poster is a most appropriate cover. Within these pages we bring you just such action. The radioluminescent lighting for airport runways and the investigation into food irradiation for longer "fresh" time are but two of the many efforts under way. Former Governor of Washington and U.S. Commissioner of Atomic Energy Dixie Lee Ray has some cogent remarks on common sense to apply to this area.

The problems facing engineers in today's society are greatly exacerbated by the lay public who would rather "believe more than think more". The tremendous successes of U.S. engineering have given the U.S. and the world a significant improvement in the quality of life, yet there are some who cannot understand the concepts of a project. They lead crusades which cost the country time, money and continued leadership. Ideas brought to practical application wind up as production capability, employment and financial success.

The universities of this country are all accepting the "land grant college" challenge of teaching, research and public service. Each part of the tripartite effort supports the other. Teaching is greatly enhanced by the involvement of faculty and staff in research and public service. Research prospers from the active participation of faculty, students and informed members of the general public. Public service helped by teaching and research moves new ideas the the public benefit rapidly and efficiently.

Research is essential for the high latitudes since many successful engineering projects cannot be directly translated to application in the north. Northern problems are usually unique or have a slight twist in physical phenomena that must be evaluated here.

"Turning Ideas into Reality" must be tried to find limits, conditions, and to assure success and safety. One such project is the review of irradiation which has been so productive in the Lower 48 and Europe. The reduction in basic bacteria provides for longer "safe times" and reduced degeneration of food. Obvious potential winners would be the fishing industry, the other parts of our food industries and grain production.

The use of radioluminescent lights has the potential of vastly improving the use of remote airports and landing sites without the costs of generators, wiring and fuel. This has possible safety implications, as well as service to the bush community.

It is hoped that the articles which follow will improve understanding of the activity of your University and especially your School of Engineering. Our efforts are in support of Alaska's future. Your comments are invited and solicited.

THE **NORTHERN ENGINEER**

The School of Engineering
University of Alaska Fairbanks

Volume 19, Number 1
Spring 1987

IN THIS ISSUE . . .

COVER

Our cover depicts the Engineers Week "Turning Ideas into Reality" art and was originally designed for the National Society of Professional Engineers' Indiana Society as a 50th Anniversary commemorative poster. The design is the work of the Indianapolis firm of Young and Laramore, an award-winning ad agency. Designer Jeff Laramore depicts an engineer's mind as the idea source from which spring a variety of basic concepts which graphically become more detailed as they float upward. Engineer's Week will be held February 21-27, 1988.

The Northern Engineer (ISSN 0029-3083) is a quarterly publication of the School of Engineering, University of Alaska-Fairbanks. The magazine focuses on engineering practice and technological developments in cold regions, but in the broadest sense, including articles stemming from the physical, biological, and behavioral sciences. It also includes views and comments having a social or political thrust, so long as the viewpoint relates to technical problems of northern habitation, commerce, development or the environment. Opinions in the letters, reviews, and articles are those of the authors and not necessarily those of the University of Alaska, the School of Engineering, or *The Northern Engineer* staff and board. Address all correspondence to THE EDITOR, THE NORTHERN ENGINEER, SCHOOL OF ENGINEERING, UNIVERSITY OF ALASKA FAIRBANKS, FAIRBANKS, ALASKA 99775-1760, U.S.A. The University of Alaska is an EO/AA employer and educational institution.

I Wonder If. . .
SPECULATIONS ON THE GEOMORPHOLOGY OF INTERIOR ALASKA

by Nils I. Johansen, P.E.

One of the advantages of being an engineer is the freedom to speculate on geology, unencumbered by geologic facts. The mind wanders freely, slips back in time to see the landscape of the past, or at least a layman's version of what the landscape may have looked like; an "I wonder if. . ." or a "what if. . . ." After living in the Fairbanks area these last 15 years, running field trips, doing consulting work, and just driving around or flying over the area, I find that several "what ifs" regarding the local geology have emerged.

Let me start close to home: Sheep Creek Road from the intersection with Old Nenana Road (now Gold Hill Road) to the intersection with Murphy Dome Road. The road follows a broad, low divide between the Ester Dome complex and the hill where the University sits (I often wonder if that ridge has a name) and the area to the north, the ridge complex between Goldstream Valley and Fairbanks. (Again, what is the name of that ridge? Today we name subdivisions, but what about the hills themselves?)* When the area around Sheep Creek Road was drilled for the new Parks Highway, the field engineers found rounded gravel, similar to what we see in the old mine tailings around town—coarse, slightly rounded, water-worn, sandy gravel. When we look at a map of the area, several features become apparent. There is a general alignment from Spinach Creek through this divide. Did Spinach and upper Goldstream creeks originally come through here, forming a tributary to the Tanana? Subsequently, Goldstream Creek may have worked its way up from Minto Flats and captured the headwaters.

But a simple stream capture does not end my speculations. There is obvious structural control in the area. Take the depression containing Smith and Ballaine lakes; bedrock is at least 200 feet down at Ballaine Lake.

And what about the pingos north of Ann's Greenhouse at mile 4 Sheep Creek Road? All this leads me to suggest that there is a system of folding and faulting. The folded ridges may have fault boundaries. After all, the groundwater feeding the pingos in Goldstream valley may come from fault-induced cracks in the permafrost. But suppose there is yet another alternative for the Sheep Creek Road valley. What would have happened if the Tanana drainage were blocked somewhere downstream? Ponding would occur until the water would spill over the low area by Happy and rush down Goldstream Valley? Goldstream Creek today is an underfit stream; that is, the stream is too small compared to its valley. The addition of the Tanana River, at least for some time, would explain the apparent incongruity between the large size of the valley and the small stream. But maybe this is but a smaller portion of an even larger puzzle.

What if the area has undergone regional subsidence? The Tanana Valley appears to have fault boundaries and to be sinking. Debris from the emerging Alaska Range to the south fills the whole valley. The regional settling of the valley is shown where the Tanana River has been pushed up against the hills on uplands to the north. A "what if" scenario could be that the Tanana flowed down Goldstream at some time, and that continued subsidence of the Tanana Valley then rerouted the Tanana River back to its original course. There is also evidence of alluviation or lakes in the Tanana Valley, ponding according to some. A "Lake Fairbanks" may have drained across the saddle at Happy. Higher terraces exist in the Tanana Valley too. The terraces have been described by A.H. Brooks of Brooks Range fame and others as well. The topography also displays other peculiarities, the way I see it. Could Chena Ridge in part be a bench, and could the top of the University ridge indicate a former terrace level? Subsequently, could the Tanana River have been lowered by the tectonic activity responsible for lowering the Tanana Valley?

**Editors note: Suspecting that there were indeed names for these features, we checked with Jim Kari of the Alaska Native Language Center, UAF. The University's home ridge, sometimes called College Hill, was known to the local Athabaskans as* Troth Yeddha' *or "Indian Potato." As for the ridge complex to the north, the local residents called it* Tok'a Ddhela' *or "Timbered Valley Mountain."*

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Now, let me follow this reasoning further. If the Tanana Valley has indeed been lowered by tectonic activity and we know that loess deposits in general occur downwind from the waterways and streams that are the source of that fine rockflour-like material, and further that lakes are geomorphic anomalies, then maybe the headwaters of the Kuskokwim River used to be the Chatanika River drainage. The general alignment fits; there are loess deposits in the McGrath area where no major drainage is present today and the low spot in the broad divide by McGrath contains Lake Minchumina. If the Minto Flats portion of the Tanana Valley had sunk, that would effectively have left the drainage divide between the Tanana and Kuskokwim in the vicinity of Lake Minchumina just where it is today. The new base level for the Tanana Valley would then be the confluence of the Tanana and Yukon rivers.

Upstream, the Tanana would also have been affected. Brooks (in the book Blazing Alaska's Trails) suggests that the Tanana originally drained to southeastern Alaska. This drainage may have been disrupted or effectively reversed by the emerging of the Wrangell Mountains and the lowering of the Tanana basin, so that now the Tanana flows to the west.

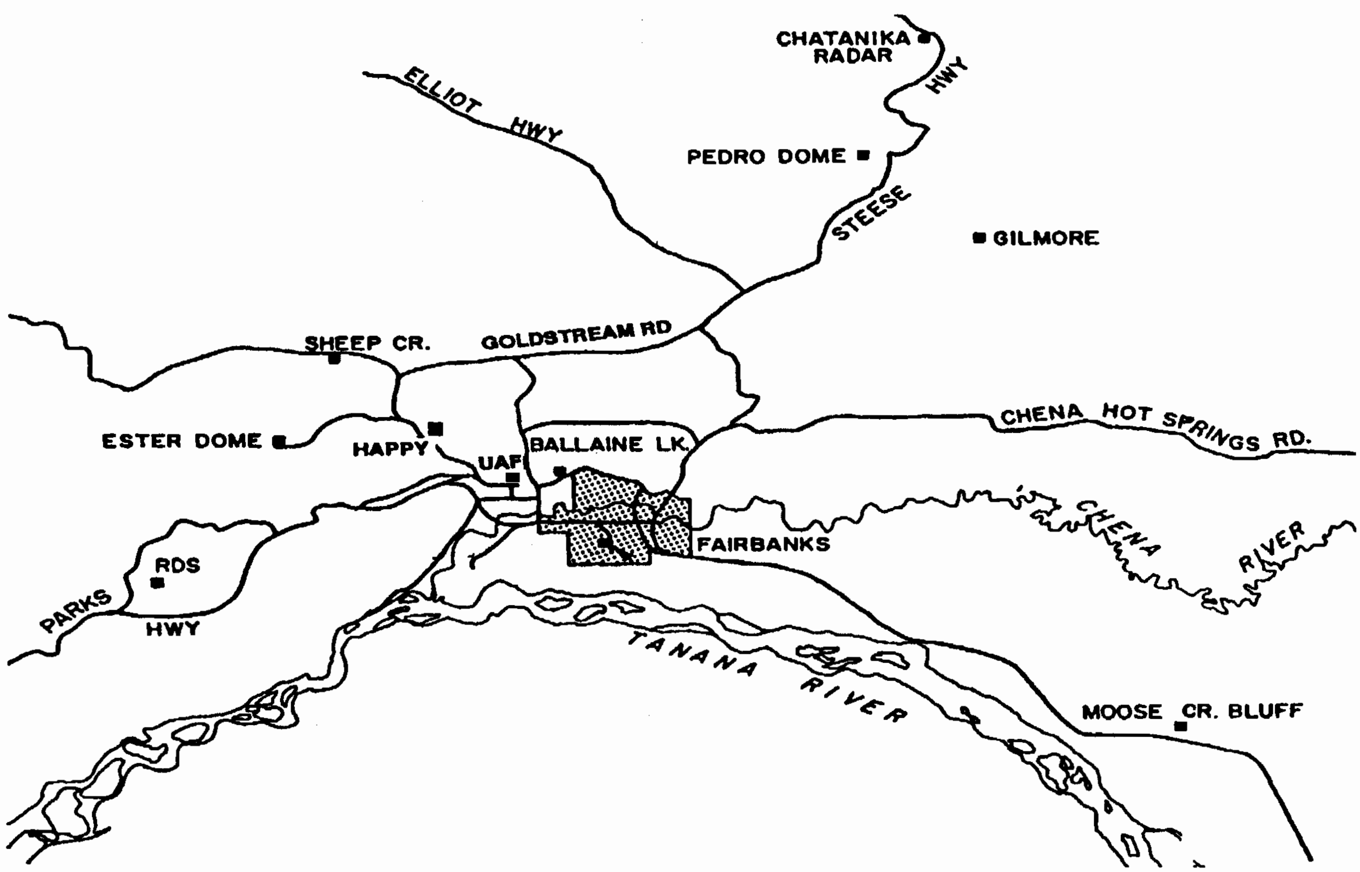
What other speculations would support these ideas? Consider the upper Chena River. I think I can see a composite valley in the Granite Tors area, indicating at least two cycles of valley development. The Chena River itself is underfit and the valley partly backfilled with alluvium, and of course the base level for the Chena is the Tanana. Now, whether the composite valley is from early Pliocene times, suggesting valley glaciation, or whether it just reflects changes in the base level of the Tanana Valley, well. . .?

So, in summary, the case for significant drainage rearrangement in the Tanana Valley area may rest on circumstantial evidence, but on the other hand ". . .why not?"

Acknowledgement: I appreciate the many members of the Department of Geology and Geophysics here at UAF. They have patiently listened to and encouraged me over the years. Engineers need good colleagues like them.

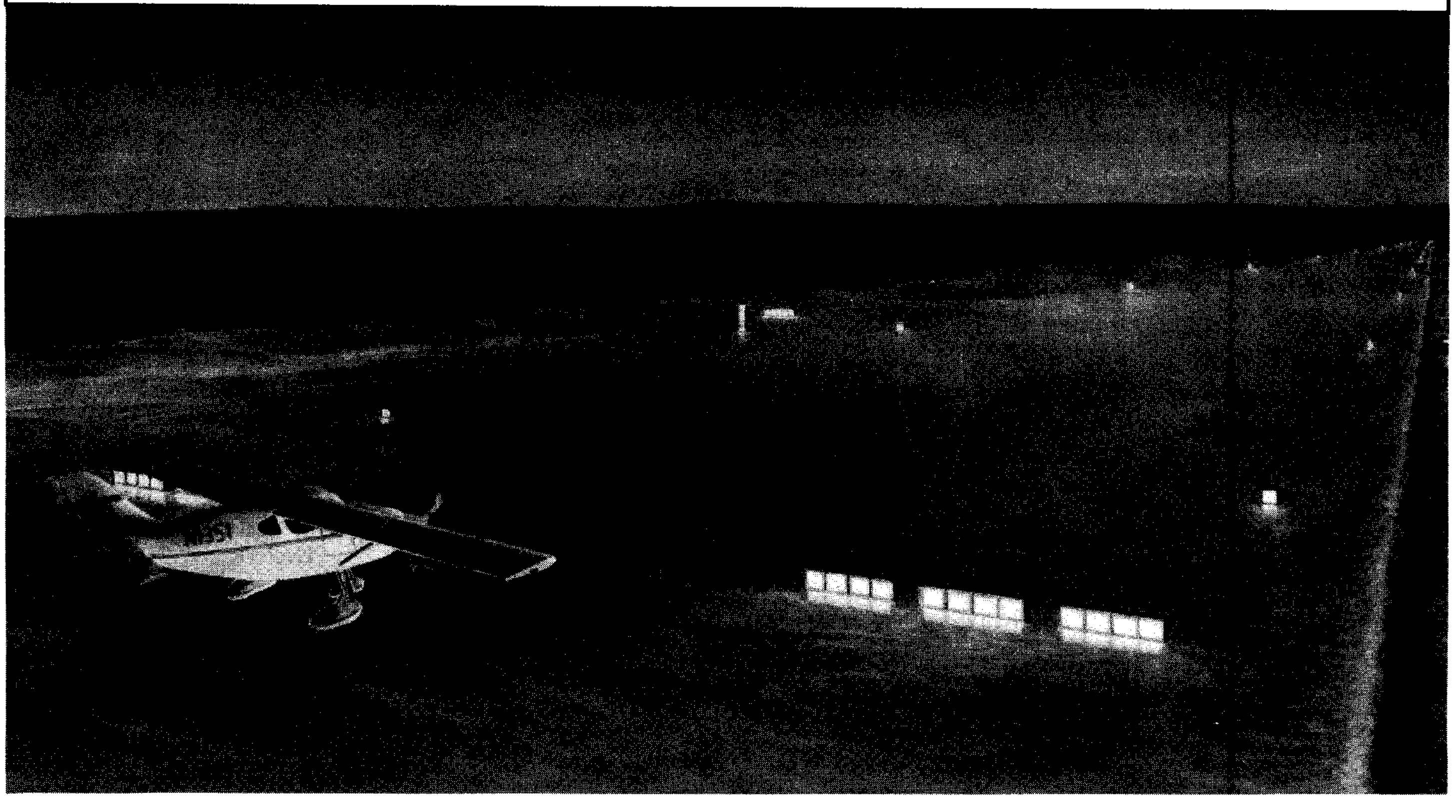
REFERENCE

[1]Brooks, A.H. 1973. Blazing Alaska's Trails. University of Alaska Press, Fairbanks, 567 pp.



RADIOLUMINESCENT LIGHTS SCORE HIGH IN VFR NIGHT AIR TAXI TESTS

by
George A. Jensen,[a] Lee E. Leonard,[b] and Judith A. Powell[a]



Alaska and other far northern areas have logistical, environmental and economic problems that make tritium-powered radioluminescent (RL) lighting, especially at airfields, an attractive alternative to electrical systems and flare pots. RL lights have been under development by the U.S. Department of Energy (DOE) for use in tactical operations and wherever electrical utility or portable power is unavailable or difficult and uneconomical to obtain. Tests and demonstrations of prototype systems in Alaska have already proved the technological value of RL airport lighting systems for both civilian and military use. User organizations such as the U.S. Department of Defense (DOD) and the State of Alaska Department of Transportation and Public Facilities (DOT&PF) have funded work through the DOE to meet their specific objectives.

The State of Alaska requested appropriate Federal Aviation Administration (FAA) approvals for use of the technology as a safe alternative lighting system to meet airfield lighting needs for air taxi operations and general aviation in the state. As a result of this request, the lights were tested by pilots, as described here, specifically to provide a formal initial evaluation of an RL runway lighting system that could lead to FAA approval for use in nighttime aircraft operations under Part 135 of the Federal Aviation Regulations (FAR). All testing was completed under high-visibility visual flight rules (VFR) conditions (10 statute miles or greater). The FAA test supervisor concluded that the RL system was acceptable under the good meteorological conditions prevailing then. However, more testing will be needed at or near VFR minimums (2- to 3-statute

[a]*Pacific Northwest Laboratory, Richland, Washington 99352*
[b]*State of Alaska Department of Transportation and Public Facilities, Fairbanks, Alaska 99701*

mile visibility) before full approval is obtained. Pilots' responses in this test and in other tests have provided much information and given incentive to the development of RL lights.

Test work was performed during September and early October 1984 at a selected rural runway near Richland, Washington. Tests were conducted by the Pacific Northwest Laboratory (PNL) for the DOE Defense Byproducts Production and Utilization Program. FAA and Oak Ridge National Laboratory (ORNL) participation in the test was coordinated by State of Alaska and PNL personnel. The goals of this flight testing were to:

- Further evaluate human factors (i.e., pilots' performance) and other factors affecting the lights and their use.
- Evaluate landing procedures for Category A aircraft[c] using the lights and suggest modifications in existing procedures that could be used by higher performance aircraft. Most pilots using the RL system for civilian aviation will be flying smaller, Category A, lower performance aircraft.

Test results were very favorable. All pilots could identify, maintain contact with, and use the runway from a minimum of 1.5 nautical miles (NM) during approach and in preparation for landing. (This distance exceeds the minimum 1.3 NM required in the criteria for Category A aircraft.) Although full-stop or touch-and-go landings were not permitted by the FAA safety pilot, most pilots felt that they would have no difficulty landing to the lights. Pilots also reported that they could use the lights for runway alignment from distances greater than 2 miles under very dark, clear conditions and between 1.5 and 2 NM under 3/8 to 2/3 moonlight and hazy conditions. Some pilots and observers reported visual contact with the runway at 3 to 5 NM along the extended runway centerline and 2 to 2.5 NM when 90° from the runway direction.

THE FAR NORTH NEEDS MORE RELIABLE LIGHTING

All rural residents of the far North share one common disadvantage: they are at the end of their nation's supply line for goods and services. Many communities simply have no access to ground transport. Furthermore, at various times of the year, many roads and rivers used for transporting goods and services to small communities can become impassable, and air transport then becomes the only lifeline for these communities. Winter weather and the brief daylight severely limit the hours that aircraft can operate without sophisticated airport systems, including runway lighting and marking. In Alaska and northern Canada, however, few rural runways are lighted or have improvements beyond a level landing surface.

Furthermore, ground maintenance and operations are often interrupted by equipment such as batteries that fail in the cold. The result is that commercial carriers must employ more aircraft and more pilots to operate during the limited daylight hours to provide safe, reliable service to rural communities. And similar conditions prevail at tactical military airfields and remote installations in the far North. All these factors increase costs greatly and put added pressure on civilian and military pilots to fly under marginal conditions. Both efficiency and safety should increase significantly if these airfields[1] and runways are equipped with the newly developed and tested reliable RL lights.

ALASKAN AIRFIELD LIGHTING

Currently two types of airfield lighting are commonly used to aid commercial night flying operations in rural Alaskan locations. One is highly developed, the other is crude. Both are specified by U.S. government regulations.

The first type, fully approved by the FAA, includes medium-intensity runway lighting (MIRL) and high-intensity runway lighting (HIRL) systems. These systems include electric incandescent runway edge and threshold lights, blue taxiway lights, a rotating locator beacon, and a lighted wind direction indicator. These are the systems found at airfields near large cities, community general aviation airports and airfields, and some Alaskan village airfields.

The second lighting system uses flare pots or lanterns to mark the area used for takeoff or landing. This method is used only at airfields near remote villages for emergency nighttime landings. Operators using flare pots or lanterns for takeoff and landing of aircraft carrying emergency supplies or passengers must obtain special approval by the FAA regional administra-

[c]*These are aircraft having landing speeds of 90 nautical miles or less per hour.*

tion. While MIRL and HIRL systems are specified in detail by the FAA, flare pot and lantern lighting systems are poorly defined, and no information on construction or preparation is given by the regulations.

Permanent military airfields have requirements similar to those of the FAA. Two additional portable systems are available to the military for tactical or emergency use. The first system uses battery-powered compact beanbag lights placed as required on the runway. The second is a system of portable runway lights powered by conventional diesel- or gasoline-fueled generators. These lights are mounted on stakes and placed along the runway as required and must be individually wired during installation.

Each portable system has significant drawbacks in the remote North. At the very low winter temperatures, batteries freeze, portable power generators are unreliable, wiring and its insulation become brittle and break. Failures occur frequently. In contrast, RL lights are self-powered and unaffected by heat or cold, and they demonstrate the ensured reliability so necessary in remote regions. They are proven environmentally safe.[2] It is expected that RL light systems will first be used to replace flare pots or lanterns for air taxi operations in Alaska on selected existing airfields. After further development and proven performance there, RL airfield lighting may eventually provide an alternative to MIRL systems for many remote civilian and military uses.

CRITERIA ARE DEVELOPED FOR THE NEW TECHNOLOGY

As RL lights are a new technology for lighting aircraft runways, criteria were developed that permit pilots to gain the advantages of the system while not compromising safety. Thus the Alaska DOT&PF, aided by PNL, developed the following criteria based on discussions with the FAA:

1. RL lighting systems will consist of the following components:

   - modular RL light fixtures (panels, etc.) placed along both sides of the runway beginning at the threshold and located at a maximum of 400-ft intervals ending at the opposite threshold;
   - a spatially separated array of RL lights placed along the left-hand edge of the primary approach end of the runway to provide visual glide slope information;
   - an electric strobe beacon located a maximum of 1 mile from the runway; an alternating white and green color pattern will flash about 15 to 20 flashes per minute.

2. Performance criteria will be as follows:

   - RL edge lights will outline the runway brightly enough that a pilot with average visual acuity can positively determine the aircraft's orientation in relation to it while conducting normal aircraft maneuvers within the airport traffic pattern.This would include maneuvering to crosswind, downwind, and base legs and circling at a radius and altitude appropriate to the type of aircraft operating on the runway as prescribed in FAA's flight training handbook. For aircraft with approach speeds of 90 knots or less, a minimum of 1.3 NM beyond the landing surface perimeter is required. This will apply under any night VFR conditions in which operations are permitted under appropriate FARs. The illumination shall also be sufficient to permit the pilot to begin and maintain a stabilized final approach immediately on completing the base to final turn when following the RL-VFR operational procedure described below (Item 3).
   - The RL visual glide slope indicator shall be bright and clear enough to indicate for a pilot with average visual acuity the aircraft's adherence to the glide slope appropriate for the terrain[d] (normally 3°) beginning not less than 1 statute mile from the threshold during a stabilized final approach. This requirement shall be valid for any night VFR condition permitted under the appropriate FARs.
   - An electrically operated locator strobe beacon will be mounted so that it is clearly visible at least 10 statute miles from the airport to an aircraft flying at 5000 ft above ground level (AGL) during a night VFR condition where visibility is 10 statute miles or more.

[d] *This may be impossible where mountains or similar terrain variations are close to the airport.*

3. At an airport with RL runway lighting under night VFR conditions, the following flight procedure will be followed:

- The pilot will navigate to the vicinity of the airport by whatever means are at his disposal.
- Upon approaching the airport vicinity, the pilot will try to identify the locator beacon, which will be distinguishable by its alternating white and green flashes. The pilot will fly a course intended to overhead the beacon [that is, fly directly over it] while starting a preliminary descent at a rate appropriate to the terrain and intended to reach about 800 ft AGL upon arriving at the beacon.
- On approaching the beacon, the pilot will identify the runway and its orientation by the RL edge lights. The pilot will continue to fly to the beacon, overheading the airport and maneuvering the aircraft to enter the appropriate downwind leg[e] of a normal VFR traffic pattern. Continuing downwind, the pilot will begin to turn base leg [that is, perpendicular to the runway] at about a 45° angle from the end of the runway. A descent should be started at the beginning of the turn to base, continuing in a normal VFR traffic pattern, and turning to a final approach intended to intersect an extended runway centerline about 450 ft AGL and assuming a stabilized approach to a landing aided by the RL visual glide slope indicator as required.
- A pilot unfamiliar with the airport should adjust the procedure described above as follows: Initiate a preliminary descent intended to overhead the beacon at an altitude of 1500 to 2000 ft AGL. At this point identify the runway and proceed to enter the normal VFR traffic pattern, circling the airport while descending to about 800 ft AGL, entering the appropriate downwind leg, and proceeding as above.[f]

For the test and evaluation, the minimum acceptable criteria for the RL lighting system were modified from those above as follows:

- The RL system must be bright enough to provide immediate recognition of the aircraft's orientation to the runway while maneuvering at 1000 ft AGL at all points in the traffic pattern within 1.3 NM of the runway. Once seen, the RL runway and threshold lights must provide this immediate recognition throughout the airport traffic pattern and approach. The mere detection of a light source indicating a runway without recognition of its orientation is not acceptable.
- The RL system must meet this operational criterion under the following conditions:

  a) prevailing minimum visibility of 2 to 3 statute miles.

  b) clear moonlit night where the contrast between the runway surface and the adjacent area is insufficient to define the runway without the aid of runway edge lights.
- The system must include a low-powered electric (strobe or rotating) airport beacon within 5000 ft of the runway and bright enough to identify the runway/airport at 10 statute miles in unlimited visibility conditions.
- The system must include an illuminated indicator that can provide wind direction information to a pilot overflying the runway at pattern altitude. (Base criteria did not specify it, but this test used RL illumination.)

While the distance criterion of 1.3 NM described above has been developed for Category A aircraft[g], the lighting system could be adapted to larger, higher performance aircraft after more experience with the system is available.

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[e] *Determined by a lighted wind indicator or direct radio communication with observers on the ground. The pilot is also advised to use the overhead of the airport and the downwind leg to look carefully at the landing surface for any hazardous obstructions..*

[f] *RL lights are of low intensity and not intended to provide positive visual reference beyond the limits of a normal traffic pattern (1.3 NM beyond the perimeter of the landing zone), although they may be visible at much greater distances under favorable conditions. The locator beacon is intended to be the only visual navigational reference outside the normal traffic pattern boundary. Thus the pilot is advised to always follow the above procedure, noting the positional relationship of the aircraft, beacon, and runway during all operations. If, while maneuvering near the airport, the pilot must operate outside the normal traffic pattern boundary (e.g., to accommodate other traffic), correct procedure requires that an approach to the beacon again be started, entering the pattern as described above.*

[g] *Reference 7 provides a more detailed discussion of this procedure..*

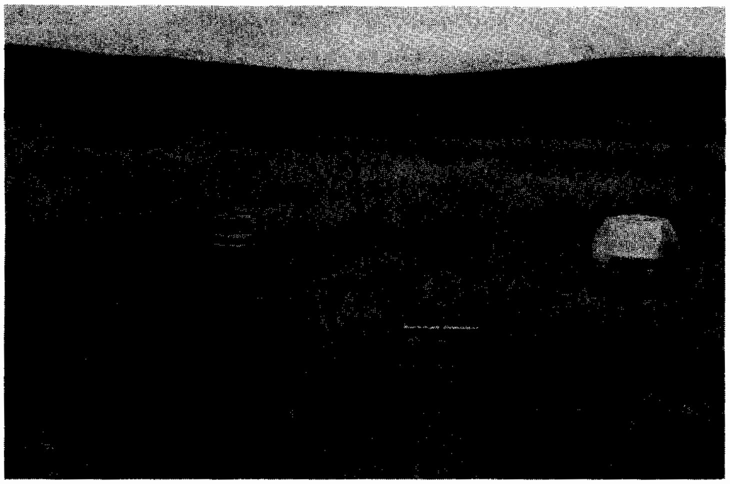

Figure 1. Strobes evaluated

THE TEST PROCEDURE IS DEVELOPED

Using these criteria, FAA Technical Center personnel developed a three-phase test procedure in coordination with PNL and State of Alaska DOT&PF. Each phase was completed twice for a left- and right-landing pattern. In Phase I, the subject pilots were flown to three locations 1.3 NM from the runway. At each location, they were told the general location of the runway and the safety pilot asked if they could clearly see the runway. The subject pilot was required to announce his position by using one of the following terms: "runway centerline," "45° to runway," or "abeam of runway" [that is, 90° to the centerline of the runway]. In Phase II, the pilots were located at a flight path parallel to the runway centerline (downwind leg) and given control of the aircraft. The safety pilot then directed the subject pilot to complete the approach to the runway and make a low flyover to demonstrate that he had the required alignment position for landing. In Phase III, the safety pilot flew the aircraft to a location between 4 and 5 miles from the airport. The subject pilot was then given control of the aircraft and asked to locate the airfield using a battery-powered strobe (Figure 1) placed about 1 mile north of the runway. The pilot then overflew the runway, located the wind T (wind direction indicator), identified the direction it was pointing, and made the appropriate downwind, base, and final low approach. Each pilot filled out a questionnaire and added comments at the end of the test.[h]

The criteria for selecting pilots were based on having subjects with air taxi qualifications and experience. Thus pilots were required to have a minimum of 500 hr flying time, an instrument rating, and a commercial rating. The 20 pilots participating included FAA flight standards personnel, a NASA test pilot, volunteers from the flight service supplying the aircraft, and several local pilots. Locally available Cessna 206 and 172 aircraft were chosen for the tests because they are typical aircraft used for air taxi operations in Alaska.

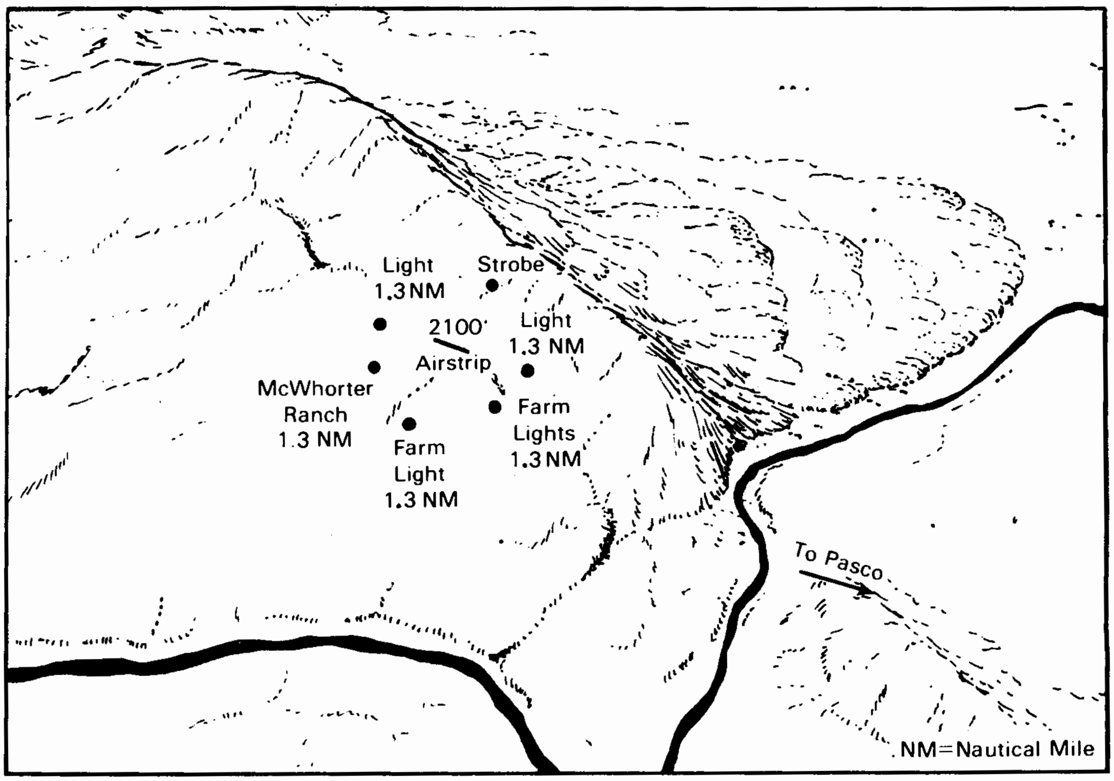

Figure 2. Site of FAA test

[h]*Category A aircraft are the primary aircraft used for air taxi operations in Alaska.*

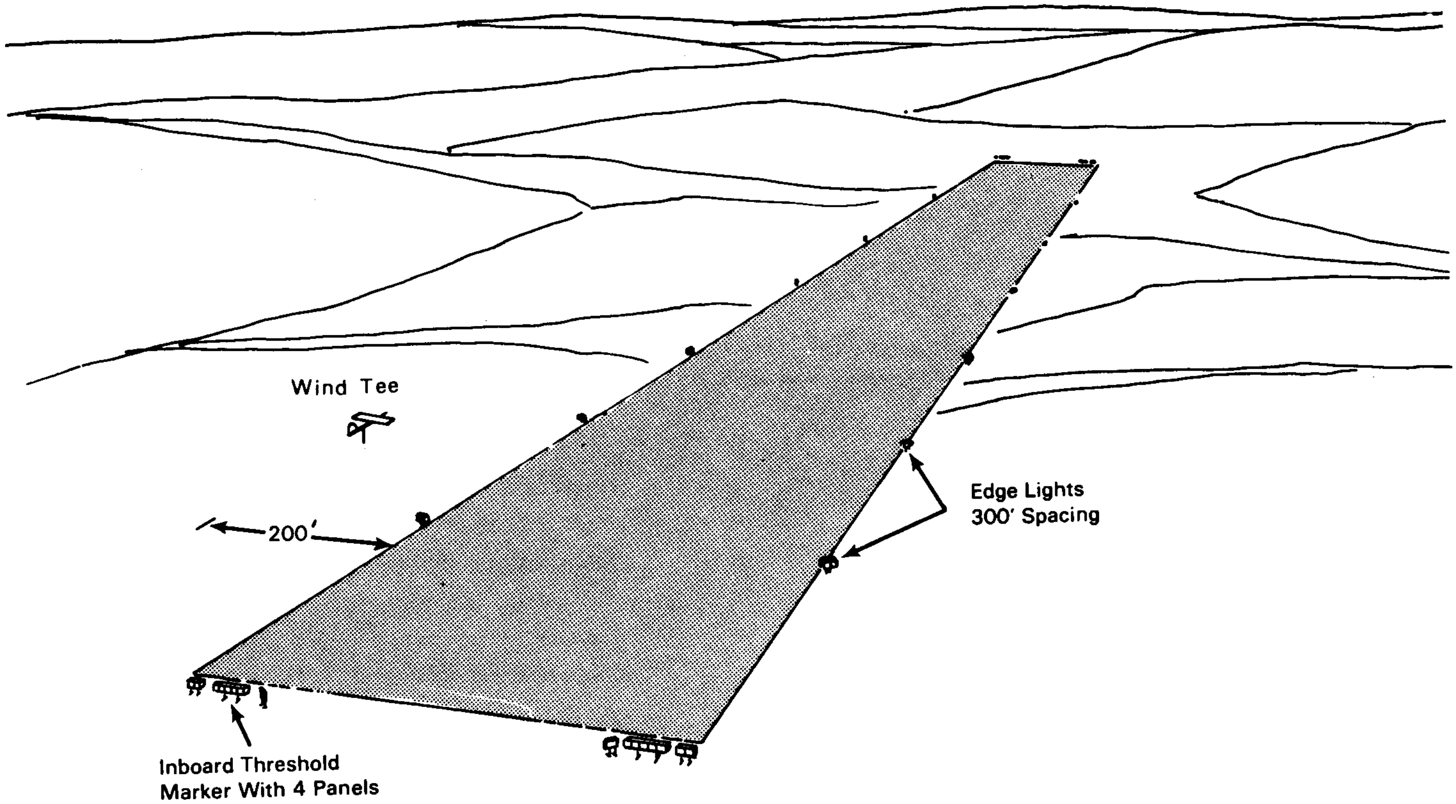

Figure 3. Flight test runway

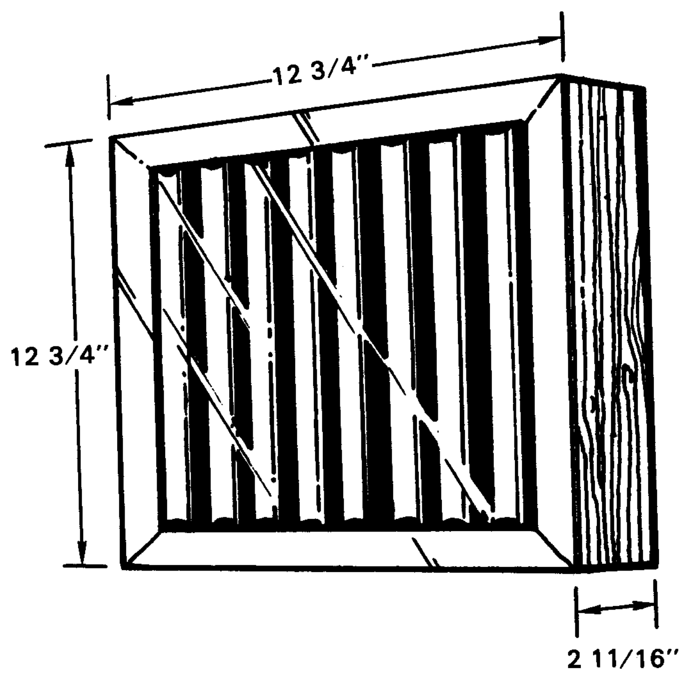

Figure 4. Radioluminescent lighting panel

THE TEST IS IMPLEMENTED

The site selected by the FAA test supervisor and the PNL test director was a dirt strip near Benton City, Washington (Figure 2). This test site was chosen from among several because it was located: 1) in a relatively remote area, free from much ambient light, 2) in an open field with the same terrain and foliage as the area surrounding the test landing surface, and 3) within about 25 miles of the major community from which the subject pilots and aircraft resources could be drawn. Moreover, its rural character resembled Alaska and there were longer periods of darkness during the planned test period than in Alaska.

The 2100-ft runway was configured as shown in Figure 3. Incandescent 1.3-NM markers were placed as needed to identify distance (Figure 2). The runway was shorter and narrower than identified in the FAA test plant, and the minimal contrast between landing surface and surrounding area required that lights be used to define the runway. Since touch-and-go and full-stop landings were not permitted, this difference was of little concern. Six RL lighting panels, using the newer tritium

Figure 5. Edge lighting fixture

tube design developed by Oak Ridge National Laboratory during 1983,[2,4,6] were mounted in newly designed edge light support fixtures (Figures 4 and 5). This fixture, evaluated in static tests on DOE's Hanford Site, was found to give better illumination than those designed for earlier Alaskan testing.[2,3,5,6] The thresholds were constructed using 14 RL light panels mounted in a mixture of the edge light fixtures and those designed and used in Alaska (Figure 6). A lighted wind T consisted of 12 RL light panels mounted horizontally on a T-shaped channel (Figure 7). The channel is free to turn toward the prevailing wind and resembles a small airplane whose alignment indicates the required landing direction.

Each of the 20 participating pilots departed from and returned to the Tri-Cities Airport at Pasco, Washington. Each subject pilot was accompanied by the FAA test supervisor and an FAA observer when the Cessna 172 aircraft was used and by an FAA flight standards pilot, an FAA observer, and others observing the test when the Cessna 206 aircraft was used. The FAA test supervisor and flight standards pilots were also the safety pilots and in command of the aircraft. All subject pilots held at least a commercial category FAA pilot certificate, current medical certificates, and valid instrument ratings. The average experience level of all 20 pilots was 4365 flight hours; minimum pilot experience was 1600 flight hours. All pilots were briefed to ensure they understood the test procedure and the needs of the evaluation. They were also given opportunity to view several RL lights at the Tri-Cities Airport so they could see how they differed in appearance from conventional lights.

Flight testing started September 27 and was completed October 3, 1984. The night of October 3 was reserved for video and photographic documentation, evaluation of the visual glide slope indicator, and some flight tests to identify maximum ac-

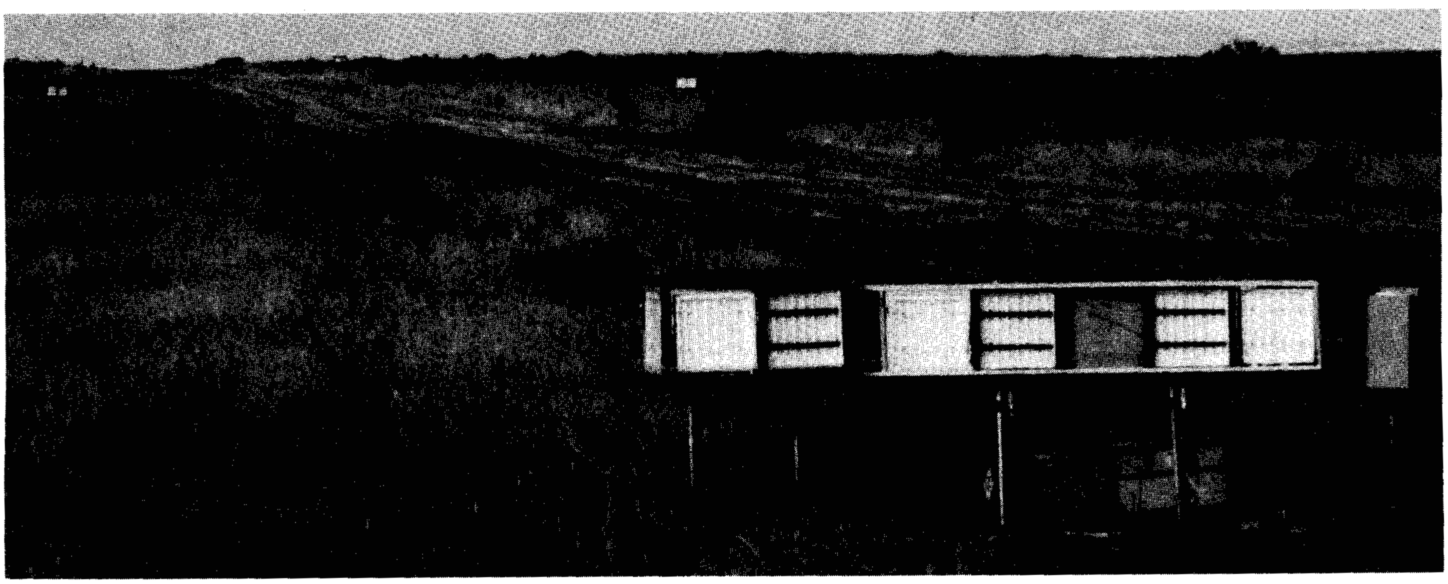

Figure 6. Threshold configuration at east end of runway

quisition distance (where the runway could first be seen). At this time following the official test, five full-stop landings were also made. The system was then disassembled and returned to Oak Ridge National Laboratory.

Figure 7. RL-lighted wind direction indicator

TEST RESULTS ARE FAVORABLE

Pilots' responses were highly favorable. Figure 8, a sample pilot questionnaire, summarizes pilot responses to Phases I, II, and III of the test. With one exception, in Phase I, all pilots correctly identified their location relative to the airfield. The one pilot corrected his initial call after noting his correct position. In Phase II, all pilots said they had no difficulty maintaining visual contact and guidance with the runway on the downwind

DATE: 9/24 - 10/2/84 Pilot's Name: 20 Pilots Pilot
Hours: Avg: 4365
A/C Type: Cessna 206; Cessna 172 Wx. Observation: Clear, 12 Statute Miles +

Phase I - Aircraft Orientation with Runway (Observer's Data)

Runway c	Position "A"	Pilot's Call:	First Run: 20 ok	2d Run: 20 ok
45°	Position "B"	Pilot's Call:	First Run: 20 ok	2d Run: 19 ok; 1 Abeam
90° Abeam	Position "C"	Pilot's Call:	First Run: 20 ok	2d Run: 20 ok

Phase II - System effectiveness in displaying runway orientation. (Subject Pilot's Evaluation)

1. While flying the downwind leg of the traffic pattern, were you able to maintain visual contact with the RL lighting system so as to judge the proper point at which to initiated the turn to base leg?
YES: 20 NO:____ ONLY MARGINALLY:____

2. While on base leg, did the RL lighting system provide the visual runway alignment guidance necessary for judging correctly the point at which to initiate your turn onto final approach?
YES: 20 NO:____ ONLY MARGINALLY:____

3. During the final portion of the approach, did the RL lighting system adequately define the outline of the runway so as to permit you to maintain the proper glide path and alignment with the runway centerline?
YES: 19 NO:____ ONLY MARGINALLY: 1

4. Did the RL lighting system provide sufficient runway definition for the flare, landing and takeoff maneuvers?
YES: 13 NO:____ ONLY MARGINALLY:____ No Answer: 7

COMMENTS:____

Phase III - Visual Approach Procedure (Subject Pilot's Evaluation)

1. From the point at which the visual approach to the airport was started, did the Airport Identification Beacon provide an adequate indication of the airport location?
YES: 19 NO:____ ONLY MARGINALLY: 1

2. While overflying the Airport Identification Beacon, were you able to verify the runway orientation (direction) and most appropriate approach direction by reference to the RL lighting system and illuminated wind direction indicator?
YES: 19 NO:____ ONLY MARGINALLY: 1

3. Would you please give your comments on the suitability of the RL lighting system for use at remote airports under the weather conditions encountered during this flight test session?
See Text

THANK YOU!

Figure 8. Pilot questionnaire and data sheet

TABLE 1. Pilot Comments (total number of pilots: 20)

COMMENT	NUMBER OF PILOTS EXPRESSING COMMENT
System was satisfactory in the weather conditions flown	13
Anticipated no problems with completing the landing	9
Use of landing lights on final approach reduces the effectiveness of the RL lighting system	7
More testing in marginal VFR weather (2 to 3 miles visibility) is needed	6
Must fly directly over the lighted wind T to use it effectively	5
Airport identification beacon essential for locating runway/airport	5
A visual approach slope indicator would be most helpful	4
Windshield glare, due to instrument reflections, can cause temporary loss of guidance	4
High on final glide slope due to relatively low intensity of RL lighting system and "black-hole" effect	2-3
Lights harder to see on downwind than on base or final approach	3
Testing should include landings to full stop	2
Special training will probably be required for user	2
More ambient light could present problems	2
Wind T too close to runway lights	2
Moonlight decreases effectiveness of RL lighting system	2
Anticipated no problems with taking off	1

and base of the approach at a minimum of 1.3 NM from the runway. One pilot reported that the RL system only marginally defined the runway outline to permit proper alignment and guide path on final approach but commented that it "may take a little time to get used to dimmer lights." All other pilots responded affirmatively to Phase II Question 3, indicating they experienced no difficulty in maintaining proper glide path and alignment with the runway centerline during the final approach.

The responses to the Phase III questions were similar: No problems were experienced in locating the airstrip and maneuvering to a final approach. One pilot rated the strobe beacon as marginal but stated that it "could be located closer to the runway (otherwise, yes)." However, all pilots could identify the strobe beacon during their approach to the test site as they passed Richland, 14 statute miles from the site. All pilots indicated in their comments or responses that they believed they could have landed safely; 13 pilots answered "yes" to Phase II Question 4, five pilots responded "N/A," and two chose not to respond. Several pilots indicated that they were "high" or the runway seemed further away on final approach than it really was. All commented that once they became used to the system, this would present no problem. All pilots correctly identified the landing direction as indicated by the wind T. (Ground personnel randomly aligned the wind T for either a west or east approach.) Several pilots said they "needed to be directly over the wind T or it was not definitive."

To identify usable acquisition distance, the safety pilot requested that the subject pilots unmistakably identify the runway outline as defined by the RL system. This determination was made while approaching at a 45° angle to the runway and ranged from 1.5 NM on bright moonlit nights to 2.0 NM when the moon was dark. Table 1 lists the comments pilots expressed on the questionnaires and tabulates the number of pilots expressing each one.[7] While the statements reflect the general nature of the written comments, they are not exact quotations. Moreover, the statements are simply open-ended responses that imply no relationship to other comments, as is illustrated by the responses to the questionnaire (Figure 8). Pilot comments or concerns were also recorded by the FAA observer in the aircraft.[7]

Visibility was at least 12 miles and, with two exceptions, clear. The two exceptions were September 29, when there was a thin overcast and some haze, and September 30, when the overcast was gone, but the haze persisted. However, Pasco, Washington, 23 miles away, was still visible. The moon became a factor on September 29 when it reached 3/8 moon; it reached 2/3 moon by the end of the test period. Thus in this test the RL lights could not be evaluated at the specified prevailing minimum visibility of 2 to 3 statute miles at an altitude of 1000 ft AGL.

Some pilots and observers reported visual contact[i] with the runway at 3 to 3.5 NM along the runway centerline and 2 to 2.5 NM at a 90° angle (abeam) from the runway direction. In one case, U.S. Army personnel in a UH-1 helicopter visiting the test site reported visual contact with the runway over Benton City, 5 NM away.

TEST FINDINGS ARE SUMMARIZED

All pilots could identify, maintain contact with, and use the runway from 1.5 NM or greater during approach, and most felt they could have landed safely. In addition, pilots reported that they could use the lights for runway alignment from distances of 2 NM under very dark, clear conditions and between 1.5 and 2 NM under 3/8 to 2/3 moonlight and hazy conditions. Some pilots and observers reported visual contact with the runway at 3 to 3.5 NM along the extended runway centerline and 2 to 2.5 NM when 90° from the runway direction. Visual contact was measured during approaches from east to west or while flying parallel to, and south of, the runway centerline. Other points include:

- The use of extra edge lights may be more effective than increasing the light emission from the threshold area.
- A navigational aid, such as a strobe light, is needed to lead civilian pilots to the airfield. Once the pilot is in the vicinity of the airfield, the RL lights provide good landing aid.
- FAA flight standards pilots evaluating the lights believed they could be used for Part 135 FAR operation.
- The lights worked well under the weather conditions of the tests.
- A visual glide slope indicator was requested by pilots.
- Pilot vision and/or training may be an important factor that accounts for the variation in visual contact, usable acquisition distances, and the high approach reported by some pilots.
- Improvement in the wind direction indicator was requested by pilots.
- The test criteria and procedure developed for this test worked well and provide a model for further testing involving Category A or higher performance aircraft.

RECOMMENDATIONS ARE MADE

Several recommendations resulted when the test data were combined with other information acquired in the program:

- Although the RL lights worked well under the atmospheric conditions encountered, more flight testing will probably be needed under conditions approaching the minimum VFR criteria of 2 to 3 statute miles visibility (fog, rain, snow, etc.) before unqualified FAA approvals under Part 135 are given.
- To accomplish the above, a rural RL-lighted runway is needed for further testing to take advantage of local minimal visibility conditions when they exist. It should be near a major airport facility having appropriate instrument navigational aids to allow the test aircraft to go to and from the test site. However, it needs to be far enough from cities or towns to prevent ambient light being a significant factor.
- Further development and evaluations of candidate visual glide slope indicators are needed (Figure 9). Earlier evaluations[6] showed that the "top hat" configuration is of minimal value, but an L-shaped configuration has shown promise (Figure 9).
- The lights need to be as bright as possible. Better phosphors, enhanced reflector designs, and more efficient tube designs are possible areas of improvement. (Improved reflector designs and tube designs have since been completed.)
- The wind direction indicator should be improved. The basic design appears reasonable, but light intensity needs to be increased. (The wind

[i] *Visual contact or acquisition is defined as when an individual first sees a glow from the RL system*

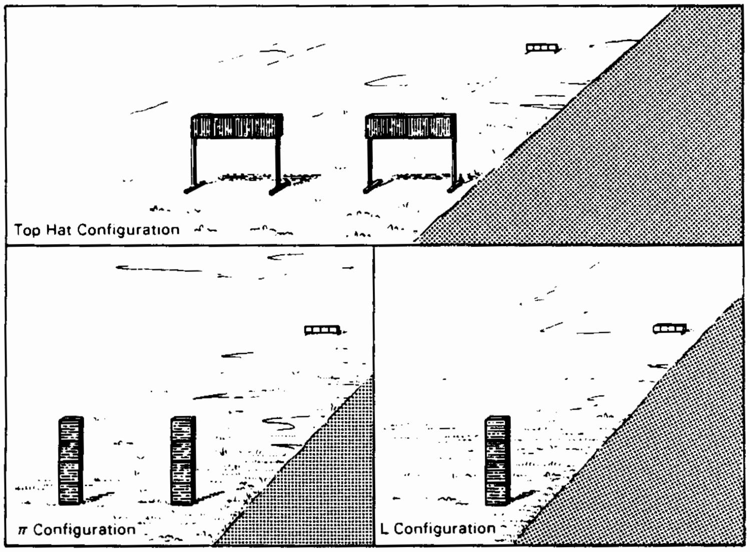

Figure 9. Possible visual glide slope indicators

direction indicator has now been redesigned to address this recommendation.)

- Participating organizations should complete an evaluation of the lights by ground testing prior to flight testing to establish an experience base for using the RL lights. This can be done using a roadway near appropriate mountain terrain.[6]

- The evaluation of human use of information should be accompanied by instrumental measurements to ensure that any relationship between human factors and actual conditions is identified. These comparative data should be useful to designers who must extrapolate findings to other meteorological conditions and provide suitable parameters for engineering designs for different locations and climates.

- Pilots will need some formal training to qualify them for air taxi operations where RL systems are used for runway marking and lighting.

ACKNOWLEDGEMENTS

This work was sponsored by the State of Alaska in cooperation with the Department of Energy Radioluminescent Lights Program under the U.S. Department of Energy Contract DE-AC06-76RLO 1830. The authors also appreciate the cooperation of J.A. Tompkins and K.W. Haff of Oak Ridge National Laboratory in this effort.

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WHAT EVER HAPPENED TO COMMON SENSE?

by

Dixy Lee Ray

Faculty, staff, students, and friends of the University of Alaska School of Engineering:

Congratulations on your dedication to excellence, which means learning and taking advantage of opportunities for education. Like everything else education doesn't take place in a vacuum; public education is the cornerstone of our nation.

I want to comment on the kind of knowledge that we call technology, what learning means in today's world, to tell you what I believe in and indulge in a bit of history. First, one outcome of learning is to believe in something. Now, lest some think me dogmatic and close minded, let me say I'm tired of wishy-washy nervous Nellie apologists, (especially nuclear ones!) Therefore, I was delighted to find this quote from English writer and Novelist Evelyn Waugh.

> *"It is better to be narrow minded than to have no mind; it is better to hold limited and rigid principles than to have none at all. That is the danger that faces so many people today—to have no considered opinions on any subject, to put up with what is wasteful and harmful with the excuse that there is good in everything, which in most cases means an inability to distinguish between good and bad. There are still things which are worth fighting for or against."*

Appropriate?? And, I add, there are things worth fighting for! There are things that are worth standing up proudly and proclaiming support for. There are things that are worth believing in!

We exercise our rights of citizenship in a self governing society by voting. I will start with a quotation from Lord MacCauley, the great English writer and novelist of the 19th century. MacCauley (1857), in a letter to a friend in America, said about democracy:

> *"A democracy cannot survive as a permanent form of government. It can last only until its citizens discover that they can vote themselves largesse from the public treasury. From that moment on the majority (who vote) will vote for the candidates promising the greatest benefits from the public purse with the result that a democracy will always collapse from loose fiscal policies—always followed by a dictatorship."*

The average age of the world's greatest democratic nations has been 200 years (we are now the oldest!). Each has been through the following sequence:

- From bondage to spiritual faith
- From faith to great courage
- From courage to liberty
- From liberty to abundance
- From abundance to complacency
- From complacency to selfishness
- From selfishness to apathy
- From apathy to dependency and
- From dependency back again into bondage.

Does all this sound familiar? Can we survive as a democratic, self-governing nation? Yes, if we exercise our innate commonsense and ask:

- What should government do?
- Why can't we balance the budget?
- What's meant by something that is "politically impossible"?
- Why perpetuate the re-election of "career politicians"? (We fought war to get rid of career politicians governing us!)

and require that our elected leaders respond to these questions.

Let me now confess my biases and my beliefs—the better for you to judge the worth of my statements:

Dixy Lee Ray is a former college professor, headed the Atomic Energy Commission in the early '70s and in 1977 was Washington's first elected woman governor. She has received numerous honors for her scientific work, including a Guggenheim fellowship. This article consists of comments taken from a speech she gave at the University of Alaska Fairbanks.

First, my biases:

I am an unapologetic, unrepentent, unabashed, unreconstructed, and unashamed supporter of knowledge, learning, and technology, including nuclear technology. I believe that they, all three (knowledge, learning, and technology), are inextricably related to liberty.

Second, my beliefs:

- I believe in learning, in the ability of humans to acquire and transmit knowledge (in spite of 26 years of university teaching; and remember, learning is the ONLY reason for universities).
- I believe that we can and should use knowledge; that knowledge not used is sterile.
- I believe that problems, which are inevitable and ubiquitous, are best solved by use of knowledge even though we seldom have enough information for perfect solutions.
- I believe that the kind of learning that we call SCIENCE, which deals in verifiable FACTS, when applied to problem solving, i.e., TECHNOLOGY, while it is not perfect, on balance it is awfully good!

Now, let's put that into perspective with a little broad history.

In mankind's long path of progress out of savagery into today's technological age, a few major achievements stand out.

The journey started with ENERGY. It began when humans learned how to use fire. Now that knowledge was not perfect, fire was not and is not totally controlled—many lives are lost and much property damage still occurs every year from uncontrolled fires—but we do not ban the use of it. The use of fire permitted primitive man to extend the variety of foods available through cooking and extend the range of habitable climates through using fire for warmth.

In a broad sense the ability to use fire led the development of agriculture and animal husbandry from which cooperative settlements and cities grew. The ability to use fire made metal working possible and led to better knowledge of materials. For 5,800 years out of the 6,000 years of known human history the burning of wood was, aside from human and animal muscle power, the prime energy for civilization. Less widely used, but important, we must add wind for sailing and windmills, and moving water for grinding grain and a few other mechanical applications. Then 200 years ago there began a rapid expansion in use of burning materials, fossil fuels; first coal and oil, then natural gas fueled the industrial revolution, and finally 100 years ago our developing knowledge of electricity made the age of technology possible.

Our society today is technically advanced—let me emphasize that, for it is the hallmark of our age. Indeed the history of western civilization is to a considerable extent the history of learning and energy use. It is also the history of unprecedented personal liberty. Our society is based on knowledge and its use. It is NOT based on wishful thinking even though some well-meaning people wish that it were. It is NOT based on emotion even though some become emotional about important issues in our society. It is NOT based on compassion, nor concern, nor sympathy, laudable as these sentiments may be. Nor is our society based on hysteria and protest. It is based on FACTS. Verifiable, determinable, repeatable facts, developed through the intuitiveness of science and the pragmatism of technology. It is not a perfect society—it is only the best that the world has ever known.

Technology touches every one. It permeates our lives. It establishes our standard of living. It affects our actions and decisions. All are influenced by knowledge, its pursuit and its use. The ultimate end is that technology is uniquely and exclusively a human attribute.

Many years ago in the early days of technology, the English writer Lord Chesterton made a wise observation. "We are perishing," he said, "for want of wonder—not for want of wonders."

And that, I think, is true today. The wonders of applied knowledge that so enrich our lives, mind you, not just the lives of a small number of wealthy elite—but the lives of everyone—have come to be taken for granted. Worse still-they are not just accepted as handy or useful or proper but they are demanded as a fundamental right. I can think of no better example of this attitude than electricity.

With electricity, anyone, by pushing a button or turning a switch, can command power unknown and unavailable to the princes and potentates and priests of all the ages past. Yet we do not wonder in awe at this miraculous power.

Let me re-emphasize that knowledge and use of electricity makes our technological age possible. All that we call HIGH TECHNOLOGY is electricity-dependent. What Thomas Edison said about the light globe is true also of the computer—"It works better if you plug it in."

Electricity powers the computers and word processors, the business machines and robotics. Electricity fuels advanced industrial processes and financial transactions. Electricity makes modern communications possible from TV to telephones and satellite transmission and messages from outer space and the moon. Electricity runs all the equipment that takes the drudgery out of domestic life. Considering domestic life, what woman would give up her electric washing machine for a scrubbing board? Her electric dryer for a hand wringer and clothes line? Her vacuum cleaner for a carpet beater and broom? Her thermostatically controlled air conditioner and furnace for a wood or coal burning stove? (Only if the electricity was made by nuclear power!) Electricity and its resulting technologies have done more for liberating women than all the speeches and protests and affirmative action programs that have jolted our sensibilities. Indeed technology has always had a liberating effect—nowhere more evident than for women. Recall the very first step taken to liberate woman from true domestic bondage was the invention nf the spinning wheel. It happened sometime during the 11th and 12th century in western Europe. Now spinning had always been woman's work; weaving was done by men. Spinning was done on a distaff, a stick that looked like a long pencil, and it took nine women spinning to keep one weaver busy—but after the spinning wheel, one spinner could keep six weavers busy and women's work became valuable for the first time. Three changes occurred: women could keep dowry, women could own property, and women could inherit from husbands. This meant that women could support themselves and not have to marry, hence the term—SPINSTER.

For a long time after the introduction of the spinning wheel there was no real progress until the energy-fueled industrial revolution, and then the development of the sewing machine, telephone, and typewriter opened new avenues of employment for women. Now with electrification of the home and so many other areas so that physical strength is no longer essential, women today can do anything. How strange then that it is somehow feminine to be anti-technology, they so often protest against electrical generating facilities and nuclear wastes that decay to nonharmful materials! But they don't protest about coal wastes that are much more voluminous and that release permanent pollutants: lead, cadmium, arsenic, . . !

Of course technology with its industrialization and use of electricity has not led to utopia or a life that is perfect. Neither has anything else. It is only better than all previous ways of living. In the industrial technology based nations people:

- live longer and healthier lives
- have greater relief from drudgery and hard manual labor
- enjoy a greater share of goods and services
- have more mobility
- have more personal liberty than in any other society ever conceived.

Given an average life expectancy of approximately 75 years, we've got to be doing something right—junk food, nuclear waste and all!

Mentioning these last two commodities—junk food and nuclear waste—is to recognize that technology may and indeed has had some unexpected side effects.

Of course people worry about new technologies, especially when their possible (however improbable) side effects are dwelt upon to the exclusion of their benefits.

Perhaps it has always been so. Since I have been quoting so much, I will share some more that I've found:

Lee DeForest, 1926:

> *"While theoretically and technically television may be feasible, commercially and financially I consider it an impossibility, a development of which we need waste little time dreaming."*

Dr. F. R. Moulton, Astronomer, University of Chicago, 1932:

> *"There is no hope for the fanciful idea of reaching the moon, because of insurmountable barriers to escaping the earth's gravity."*

Dr. Vannevar Bush, Testimony to Senate, December, 1945:

> *"There has been a great deal said about a 3,000 mile rocket. In my opinion such a thing is impossible for many years. I say technically I don't think anyone in the world knows how to do such a thing and I feel confident it will not be done for a very long period of time. I think we can leave it out of our thinking."*

Dr. Dionysys Lardner (1793-1859):

> *"Rail travel at high speeds is not possible because passengers, unable to breathe, would die of asphyxia."*

Napoleon to Robert Fulton:

> *"What, Sir? Would you make a ship sail against the wind and currents by lighting a bonfire under her deck? I pray you excuse me. I have no time to listen to such nonsense."*

Charles H. Duell, Director of the U.S. Patent Office, 1899:

> *"Everything that can be invented has been invented."*

Now let me quote from the Congressional Record.

> *"This begins a new era in the history of civilization. Never before has society been confronted with a power so full of potential danger and at the same time so full of promise for the future of man and for the peace of the world. The menace to our people . . would call for prompt legislative action, even if the military and economic implications were not so overwhelming."*

The year was 1857; subject: internal combustion engine! What ever happened to common sense? Now a lot of foolish, negative things are said about nuclear power. Electricity generated by the controlled release of neutrons from the nucleus of atoms (chiefly of uranium) is a present day reality. Nuclear power generates 15% of the total electricity used in the USA today. It is safe, economic, and without deleterious effect on the environment. Its wastes can be and are held isolated above or below ground until they decay to harmless radioactive levels. Adding the benefits from nuclear medicine, the use of isotopes in agriculture and engineering and the contribution nuclear science has made to expanding knowledge in all the basic sciences, it is beyond understanding how some people can be so emotionally opposed to its proper and controlled use. Remember that about 3 units of energy can be released from burning a molecule of carbon or hydrogen, but 215 million units of energy are available from every neutron impact on a uranium atom. Whatever happened to common sense? The nuclear dilemma reminds us of the fate of Prometheus at the hands of those to whom he gave the great gift of fire . . . no good deed will ever go unpunished!

I have a final comment on the government and on our nation, USA, that has made education and learning available to everyone. For those who believe in the traditional values of personal freedom and limited government, now is time the to test confidence in our ability to handle problems responsibly and to govern ourselves without hysteria.

It was just 200 years ago, in the decade of the 1780's, that the American experiment in liberty was legally and constitutionally established, leading to the greatest technological development and the greatest saga of human accomplishment and abundance known to history. The challenge to our era is to renew the faith to use our knowledge and reclaim the wisdom and reestablish the strength that made America the greatest and freest nation in the world! These are things that are worth fighting for!

IS FOOD IRRADIATION FEASIBLE IN ALASKA? SOME ENGINEERING CONSIDERATIONS

by
Ruthann B. Swanson, Charlotte I. Hok, Debendra K. Das, Carol E. Lewis

INTRODUCTION

Food irradiation is an old technology that has recently attracted much new interest. The banning of EDB, a fumigant used to control insect infestation in fresh fruits and spices, concern about other chemical treatments of food (Anon, 1982), concerns about increased levels of naturally occurring disease-carrying microorganisms that are of public health concern (USDA-FSIS, 1986), and food losses due to spoilage have combined to stimulate new interest in this technology (Anon., 1982). The release in 1981 of a study by the United Nations World Health Organization (WHO) that recommended the adoption of food irradiation to help solve these and other problems (WHO, 1981) has also increased interest.

THE PROCESS

Foods that are exposed to ionizing radiation are described as irradiated. Like canning, freezing, drying or pasteurization, irradiation is a physical process. The irradiated foods are not radioactive and the consumer is never exposed to radiation (Josephson and Bryniolfsson, 1987).

FOOD IRRADIATION IN THE UNITED STATES

The United States Food and Drug Adminstration (FDA) added fresh fruits and vegetables to the list of food items approved for irradiation processing in 1986 (Table 1). In test markets in California (Bruhn and Noell, 1987) and Florida (Puzo, 1986), labeled, irradiated mangoes and papayas sold well; the appearance and quality of the irradiated fruits encouraged consumer purchases. Currently, a proposal is pending that would allow irradiation of poultry products to reduce levels of Salmonella and other pathogens (USDA-FSIS, 1986) and a petition to allow irradiation of seafood is expected soon. Research programs have been authorized in six states by the U.S. Congress. The objective is to transfer irradiation technology to the private sector if the net benefits prove to be positive. Funds have been transferred through the United States Department of Energy (DOE) to the state of Alaska as well as the states of Florida, Hawaii, Iowa, Oklahoma, and Washington.

The Institute of Northern Engineering at the University of Alaska Fairbanks is coordinating the Alaskan feasibility study. Potential impacts on Alaska's food industries and the Alaskan consumer are being examined by an interdisciplinary team representing food science, economics, and management as well as engineering. An advisory panel from government, industry and the general public will provide additional input and expertise.

ENGINEERING ASPECTS

Engineering considerations include selection of a radiation source, recommendation of potential sites and the design of a safe and functional facility. Arctic environmental conditions will be major parameters in this decision-making process. In addition, Alaskan commodities suitable for irradiation, their production and harvesting areas, the quantities available and their market forms will also be influential factors.

ENERGY SOURCES

The United Nations' Codex Alimentarius Commission (CAC) recommends three types of radiation sources for food processing. They are: gamma rays from an isotope source, 5 MeV x-rays and 10 MeV electrons (CAC, 1984). These types of radiation (Figure 1) are frequently referred to as ionizing radiation, because they have very short wavelengths and a strong tendency to produce ions (Coon et al., 1985).

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Table 1. FOODS APPROVED FOR IRRADIATION TREATMENT IN THE UNITED STATES

FOOD	DOSE LIMIT	PURPOSE	APPROVAL DATE
Wheat, wheat flour	200 to 500 gray	Insect control	1963
White potatoes	50 to 150 gray	Sprout inhibition	1964
Pork	0.3 kGy (min) to 1 kGy (max)	Trichinella spiralis control; parasite causes trichnosis	1985
Dry spices, seeds, teas, herbs, vegetable seasonings	up to 30 kGy	Insect and microorganism control	1986
Fresh fruits and vegetables	up to 1 kGy	Insect control and maturation retardation	1986

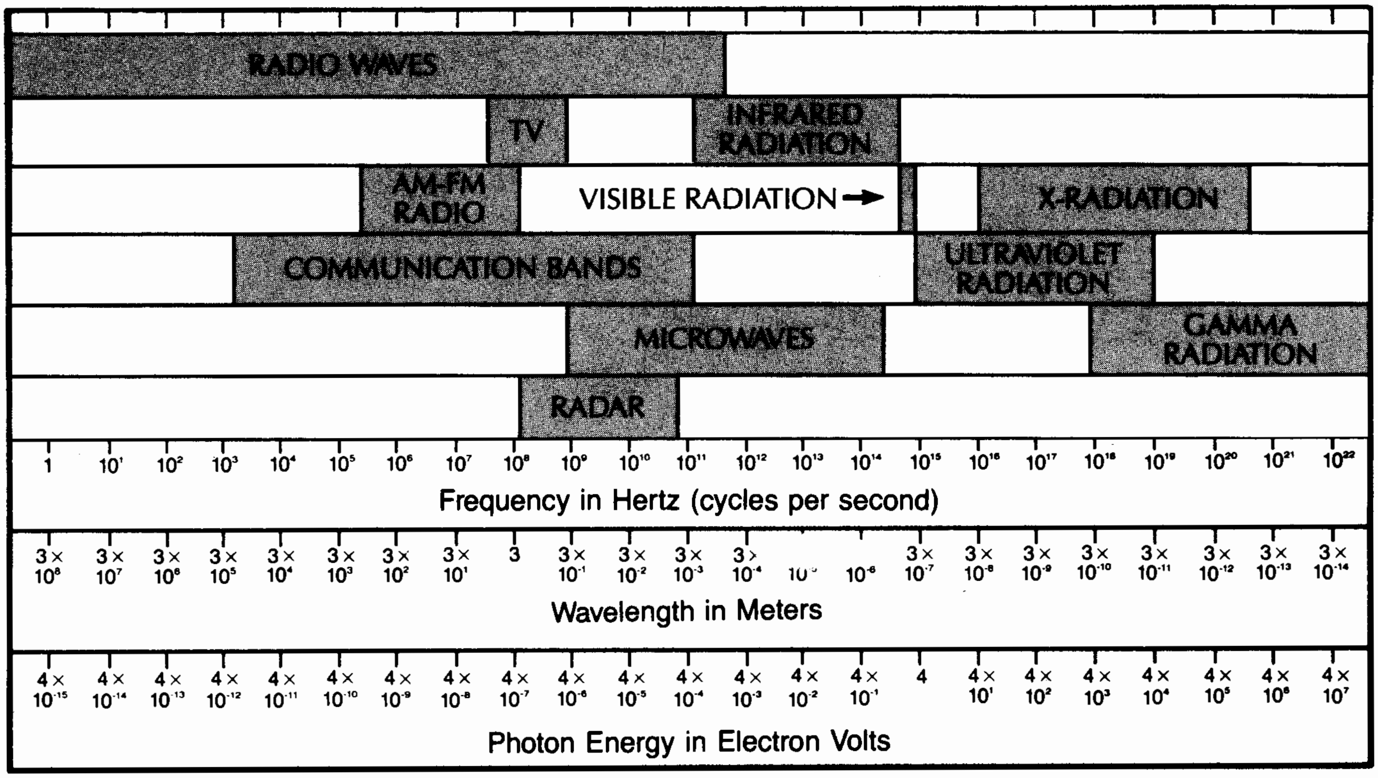
Dose levels permitted during the irradiation process are described in terms of kilograys (kGy); 1 kGy = 1000 grays. (Adapted from Lecos, 1986).

Machine-generated sources are used in the sterilization of medical products and food containers, crosslinking of plastic and rubber materials, and the curing of inks, coatings and adhesives on a wide range of packaging materials. High-energy electron beams do not have the penetrating capability of x-rays or gamma rays (Rodrigues, 1985), which may be a problem with many food products if conventional handling and packaging procedures are used. The in-line conversion of electron beams to x-rays will overcome this problem, but the efficiency of this conversion is 8% (Rodrigues, 1985). Machine technologies are being improved and are beginning to compete with the use of traditional isotope sources in food irradiation. The advantage of these sources is the alleviation of many of the potential transportation and safety concerns associated with isotopic sources. Because the ionizing energy is generated mechanically, no transportation is involved. Additionally, machine sources can be immediately and automatically deactivated should a malfunction occur (Ramler, 1982). The Occupational Safety and Health Agency sets the standards for personnel and environmental safety (Jarrett, 1985).

Most of the irradiation facilities operating in some 41 countries throughout the world, including facilities in the U.S. for medical product sterilization, use gamma isotope sources (Markovic, 1985). Both cobalt-60 and cesium-137 can be used as gamma sources in food irradiation facilities. Currently, there are limited amounts of cesium-137 available and the production of more is unlikely, making the use of this radionuclide questionable over a long-term period. Cobalt-60 is produced in Canada and adequate supplies are anticipated in the future (Sloan, 1987).

In Alaska, there are existing regulations and procedures for transporting gamma sources (Alaska Radiation Protection Regulations AAC85.320, 1978). These sources, which are currently used for medical, industrial and research purposes in the state (Heidersdorf, 1987), are transported to and from facilities in specially designed casks that have been rigorously tested. Intrastate regulations must be as stringent as the interstate regulations that are regulated by the United States Department of Transportation and the NRC. Gamma sources would not be stored in state, and spent sources would be removed by the seller for disposal. No additional waste is generated by this process (Martin, 1982).

U.S. facilities using gamma sources must meet rigid standards for leak testing, radiation detection, personnel dose monitoring, operational, training and emergency procedures and a radiation safety program (Jarrett, 1985). The source material itself is contained in stainless steel capsules and must meet specific safety standards for temperature, external pres-



The frequencies, wavelengths, and photon energies of the major part of the electromagnetic spectrum. The boundaries of the named segments are more or less arbitrary, and there is now some tendency to reduce the overlapping by defining the range between TV and infrared radiation as microwaves and the range between visible radiation and X-radiation as ultraviolet.

Courtesy of CAST magazine, March, 1985, ISSN 0194-4096.

Figure 1.

sure, impact, vibration and puncture (ANSI No. N542.) These facilities must be licensed by the Nuclear Regulatory Commission (NRC). In the extremely unlikely event of accidental contamination of the storage pool, containment, clean-up and/or disposal would be done by an authorized agent (NRC, 1984).

IRRADIATION FACILITY

Forty years of international research have resulted in rules of safety that govern the design, fabrication, inspection and quality control procedures used during the construction of irradiation facilities (Jarrett, 1985). Heavy shielding, complex mazes, electronic door interlocks and remote radiation monitors provide both active and passive safety mechanisms (Martin, 1982).

A typical food irradiation facility is shown in Figure 2. At the center of the irradiation chamber is the source (1). Although this facility is designed for a gamma source, the design is similar if a machine source is employed. When a gamma source is used, it is immersed in a pool of deionized water or a lead-lined cask that serves as a shield. The water storage pool or cask is unnecessary if a machine source is used. The irradiation chamber, itself, is completely shielded by thick layers of concrete or a lead-lined steel shell (2) on all sides.

Commodities can be irradiated in bulk or as individual units as well as before and after packaging. After placing the commodities in containers or on pallets, they are loaded on the entrance conveyer (3) and carried into the irradiation chamber. In this irradiation design, the products circle the source (4) for a predetermined period of time. Only one side of the product is exposed. After traveling outside the irradiation chamber (5), the products are rotated 180 degrees (6), and the path is retraced to allow irradiation on the other side. Once the process is completed, the containers are removed at the exit point (7) and the procedure begins again. The entire process is controlled by an

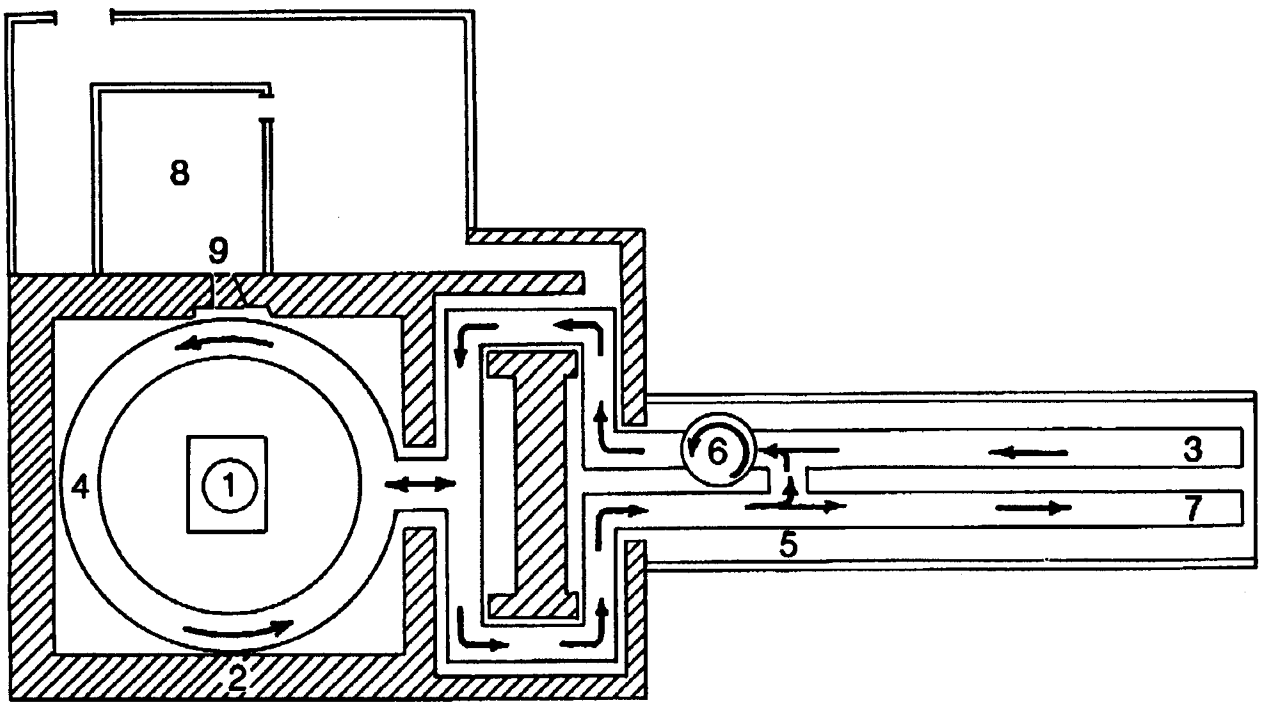


Figure 2.

operator from the control room (8) outside the irradiation chamber and can be viewed through a window (9).

According to FDA regulations, only the lowest radiation dose needed to achieve the desired result can be used (Lecos, 1986), and maximum dose levels have been established for all foods approved for irradiation processing (Table 1). Therefore, it is important to know what irradiation dose was received throughout the package, container or pallet. Dosimeters that consist of crystals or vials containing a liquid, polymers, or small pieces of film-type material are placed at strategic locations in the product. Changes in dosimeter color are used to calculate the dose (Farrar, 1987).

FACILITY LOCATION

Although many factors will influence potential locations if an irradiation facility is to be built in Alaska, final site selection will be limited by environmental considerations. Prior to final site approval, a detailed geotechnical exploration program must be conducted at any recommended site.

The depth to the aquifer as well as soil conditions are factors in identifying potential sites. Although successful designs have been developed so that foundations can be erected on permafrost terrains, the best alternative is to avoid such a site (Permafrost, 1983).

Damage caused by the 1964 Good Friday earthquake has been widely documented and is still vivid in many Alaskans' memories. Because much of the state lies in seismically active areas, this is a major factor in site selection and building design for any facility, (Intl. Conf. Building Officials, 1976). Stringent design standards have been developed for facilities that employ a radiation source (ANSI, N43.10).

Volcanic hazards exist in many Alaskan seafood harvesting regions. Site selection for any industrial facility should be outside of potential hazard zones. To avoid potential damage from tsunamis, whether generated by volcanoes or earthquakes, industrial facilities in coastal areas should be located outside of potential hazard areas (Davies, 1987).

CHARACTERISTICS OF IRRADIATED FOODS

The texture, flavor and appearance characteristics of irradiated food products at accepted dose levels are not significantly changed from those of unirradiated fresh products. Small quality changes do occur, however, because a few (6 out of 10,000,000) chemical bonds are broken in the food (Josephson and Bryjolfsson, 1987). For example, dried vegetables cook faster, meat is tenderized and some naturally occuring toxins that form during post-harvest storage are not formed when the food has been irradiated (Loaharanu and Urbain, 1982). When the food bonds are broken, a few new compounds, known as radiolytic products, are formed from the food's natural components. Athough some consumers fear that these compounds are unnatural or hazardous, most of them have been found in foods that have not been irradiated. In fact, many of these compounds are formed when foods are cooked or processed using traditional techniques (Josephson and Brynjolfsson, 1987). Because these changes are not obvious, labeling is required at both the wholesale and retail levels to indicate that the foods have been processed using irradiation (FDA, 1986).

Using present day processing techniques, nutritional quality of the foods is not impaired. Although nutrient content of irradiated foods may be lowered slightly, the effect is no greater and may be less than that found when foods are processed using traditional food processing techniques. In addition to WHO (1981) and FDA (1984, 1986), the Canadian Government (1987), the British Ministry of Health (ACINF, 1986), and the American Medical Association (AMA, 1985) are among the governmental and professional organizations that have endorsed the use of this process.

POTENTIAL BENEFITS IN ALASKA

There are several potential benefits from the use of the irradiation process in Alaska on Alaskan commodities.

- Extended shelf-life may allow the shipping of fresh Alaskan products into new in-state, and worldwide markets without degradation of quality. This could benefit the seafood industry by increasing Alaska's share of the premium fresh-fish market. Marketing of underutilized fish species with limited shelf-life may also become feasible. Fresh Alaskan reindeer products may become competitive in the growing national and international game meat markets.
- Increasing shelf-life of fresh products could aid the Alaskan food industry by avoiding market gluts, maintaining prices, providing more consistent supplies and avoiding spoilage due to oversupplied markets.
- Utilization of presently discarded by-products from the seafood and agricultural industries could eliminate some environmental concerns and increase total product value.
- Quality and selection of food products may be improved by the irradiation process, especially in rural Alaska.
- Reduction of pathogens of public health concern could improve the safety of foods available to all Alaskan consumers.

A research and development project to identify the quality effects on Alaskan products could be the next phase in the eventual introduction of this new technology to Alaska.

REQUEST FOR INPUT

At the conclusion of the food irradiation feasibility study, the research team will make a recommendation to the State of Alaska and DOE concerning the desirability of an irradiation facility in Alaska. Public comment is an important part of the study. Readers interested in making their views known to the study team should send written comments to:

Public Comment
Institute of Northern Engineering
539 Duckering
University of Alaska Fairbanks
Fairbanks, AK 99775-1760

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