

Jeffrey R. Charles

Optical Air Traffic Detection System

(Brief 1996 study, with cover letter)

This document consists of material generated by J. Charles during years he was not working at JPL.

Material that was not in the original archive file is shown in [square brackets].

Most costing information and the names of some persons and organizations have been removed.

Work shown in this document was not funded by any customer.

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In response to our telephonic conversation of Feb. 14, 1996, I am enclosing [the requested] preliminary recommendations for equipment to be used in your proposed video system which could be mounted on lasers in Las Vegas. I will refer to this system as an "Optical Air Traffic Detection System". This response will also include several questions (some of which I asked you on the phone) which relate to factors affecting the performance of an Optical Air Traffic Detection System. These questions are just an example of the many questions which must be addressed before an Optical Air Traffic Detection System can be adequately specified. In my view, there would be little point in preparing a DCT until the customer's requirements are better defined and the factors affecting system performance have been thought through more thoroughly.

This response constitutes the totality of work I am willing to perform on a speculative basis, and no claim is made as to the accuracy or usefulness of the information herein. If you would like me to pursue this project further, I am willing to do so either as a JPL employee or as an independent consultant. Due to my recent surgery, I will not be able to take on full time work for a month or so, but I may be able to work on a part time basis in the mean time. If I work independently rather than being employed by JPL, my rate will be \$[deleted] per hour plus expenses if travel and commute time is paid, with a minimum charge of 3 hours per day if I work locally and 8 hours per day if I work out of town, or, \$[deleted] per hour plus expenses if I absorb travel and commute time, with a minimum of 2 hours per day if I work locally and 6 hours per day if I work out of town, so long as travel time does not exceed half of the chargeable time on each trip. Weekends and holidays will be [charged at] \$1.5x.

Before I begin, I would like to express my concern about your funding prospects. While I wish you well on this venture, I believe it may be enlightening if I play "devil's advocate" with regard to your funding prospects. Even my limited experience at attempting to obtain project funding indicates that it will be very difficult for you to obtain either JPL funding, or JPL's cooperation in your efforts to obtain "outside" funding. In my view, the primary reason for these difficulties would be JPL's potential exposure in civil liability suits should any part of the radar/optical system fail to detect an aircraft. Potential plaintiffs could include the following:

- * The customer - if the lasers are ordered shut down by the FAA and said customer claims a resulting loss of revenue.
- * The public - if it is alleged that the police in a helicopter lost track of a suspect because of being temporarily "blinded" by the laser, and the suspect commits another crime before being apprehended.
- * The public, the police, or the military - if injuries are alleged to result from a laser illuminating an aircraft; however unlikely this may be. (Particularly if [the injuries are from] an aircraft full of kids falls on "a school bus full of [lawyers'] kids").

While most of the above scenarios are unlikely, the potential exposure of the customer (and possibly JPL) to civil liability could be significant should the system fall short of its represented ability [assuming an ability is represented] to detect aircraft. It is almost certain that you will have to specify the system's anticipated reliability before the project could be approved by either JPL or the customer. If I were the FAA, the customer, or a director of Cal Tech, I would want to know the reliability of the system and I would want to see the data which backs up the claim of reliability. The potential exposure to liability will likely mean that Cal Tech's directors, lawyers, etc., will have to sign off on the project before it can proceed. This could cause an excessively long delay. It is not unreasonable to expect that you will have to address reliability/liability issues and answer many questions such as those I have posed in the attached analysis in order to get funding and/or approval.

Background light from artificial light sources in Las Vegas will definitely cause the optical system to be the weak link in a combined radar/optical system [I would propose only a combined system, owing to the shortcomings of optical alone]; in fact, this item may be a show stopper. Preliminary investigation would lead me to categorically state that an "inexpensive" (less than \$10K) optical/video system will not be 100% effective in detecting aircraft flying at a range of 20 miles and at a 2 degree elevation angle. Reliability will obviously improve at higher elevation angles. Having said this, it may nonetheless be possible for you to provide a system which will detect aircraft with a reliability that the customer and the FAA will find "acceptable". I hope that you will find the following questions and analysis useful.

Thank you, and happy hunting!

Jeffrey R. Charles

cc:

[Name deleted]

Cursory analysis of factors which will affect system requirements for the
Optical Air Traffic Detection System
which has been proposed by [deleted]
for use with ~532 nm lasers at Las Vegas.

DRAFT 1
(speculative [all IP rights retained by the author])

Feb. 15, 1996

Jeffrey R. Charles, System Engineering Consultant

1.0 Preliminary analyses of the proposed Optical Air Traffic Detection System.

1.1 Atmospheric and lighting conditions.

1.1.1 Haze, particulates, etc. Haze, particulates, and other atmospheric effects can cause considerable extinction of distant aircraft lighting. This will obviously make a distant aircraft difficult to detect with a given sensor. Accordingly, the requirements for an adequate sensor will be rigorous.

1.1.2 Clouds. Even thin clouds can obviously obscure a distant aircraft. Unfortunately, the same clouds may not adequately dim or scatter the laser beam. Additionally, low altitude clouds may obscure an aircraft and adequately dim the beam some of the time, but these clouds can move and suddenly allow a clear view of the aircraft. The system will need to have a rapid response time and the requirements for an adequate sensor will be even more rigorous.

1.1.3 Artificial city lighting and back scatter from the laser. Artificial lighting in most cities will create a [relatively] bright [night] sky background. This will lower the SNR of an image of distant aircraft lights, particularly those at a low elevation angle. Most of this artificial light will have to be filtered out if the system is to have any hope of reliably detecting distant aircraft. It will be a major challenge to fabricate a filter which adequately filters out artificial city lighting but does not severely attenuate the image of aircraft lights. Filtering out the back scatter from the laser will probably be a minor challenge by comparison. The requirement to filter out artificial city lighting and back scatter from the laser will necessitate the use of a sensitive video system. We will assume that atmospheric conditions are "average", that affordable (i.e. "good") filtration is utilized, and that the intensified optical system has a 65 mm aperture and a 6 degree field of view. If a small aircraft has "favorable" light sources, a range of 20 miles, and a 2 degree elevation angle, the SNR of its image will probably be less than 1 dB. Detecting such a weak signal will probably require frame averaging.

1.1.4 Low flying aircraft: Low flying and fast moving aircraft will necessitate a rapid response time. Police and military helicopters may not always move fast, but they may not [always] be utilizing lights that are bright enough to be easily detected.

1.2 Instrumentation.

1.2.1 Camera and sensor. Assuming that you intend to detect any aircraft solely by its light output at the 20 mile maximum distance you mentioned, an intensified video camera will be required. I would recommend a camera with a Gen. 2 or Gen. 2+ intensifier. I do not recommend a Gen. 3 intensifier for your application because of its tendency to "burn in" when exposed to bright or prolonged light sources. Additionally, the camera should be equipped with a tapered fiber optic bundle. This will allow you to use lenses with a larger aperture and longer focal length to get a given angle of view. I would specifically recommend that you contact EOSI (Electro Optical Services Inc.; the supplier of the intensified camera acquired for DSS27) for technical information and a quote. Some of their systems offer auto gating which will help prevent damage if the sensor is suddenly exposed to bright light.

1.2.2 Optics. I would recommend either the 135mm f/2 Nikkor or the 180mm f/2.8 ED Nikkor lens for the optical system. I do not have a record of the size of the tapered fiber optic bundle used in the EOSI camera so I can't give you the field of view you would get with these lenses. A guess would be 6 degree diagonal coverage for the 135mm, and 4 degrees for the 180mm. I do not recommend commercial lenses shorter than 135mm because you will have to stop most of them down to between f/2.2 and f/2.8 to get a sharp image, and stopping the lens down will excessively reduce your aperture.

1.2.3 Comments about system configuration. Filtration of the city lights will be required in order to detect distant aircraft which are flying at low elevation angles. This will probably be the biggest challenge. Since it is likely you will need a custom filter for the task, I would recommend that the filter also be designed to filter out the back scatter from the laser. This will be simpler than relying solely on] attempting to pulse the laser in synch with gating of the camera sensor. You may have to utilize a dual optical system. The system described above would be used for closer aircraft and a large aperture narrow field system would be used for distant aircraft.

1.3 Anticipated performance. I do not believe that it will be possible for you to provide an optical system which will detect aircraft with 100% reliability. Reliability will obviously increase with elevation angle. Artificial city lighting is a potential show stopper. Most of the questions posed below will have to be addressed before system performance can be reliably anticipated.

2.0 Questions about factors affecting system performance:
(These are but a few of the many questions that will have to be addressed)

* What system reliability must be demonstrated before the FAA will approve the use of the lasers?

* What are the minimum and maximum ranges at which you must optically detect an aircraft?

* What is the minimum acceptable elevation angle for the laser beam? (Be sure that the specified angle has actually been measured rather than having been simply guessed at)

- * You stated that the laser may be pointed at a nearby (approximately 20 miles away) mountain in order to shield it from more distant aircraft. Will this always be the case?
- * What are the spectral and other characteristics of the [proposed] lasers?
- * What are the characteristics of the artificial lighting in Las Vegas?
 - * Spectral characteristics?
 - * Brightness vs. elevation angle at the azimuth of each laser?
 - * How much additional lighting might there be in the next few years?
- * What are the characteristics of the various lights used on aircraft?
 - * Spectral characteristics?
 - * Brightness range?
 - * What is the worst case that must be accommodated? (i.e. unfavorable aircraft lights, unfavorable aircraft attitude and distance, atmospheric & artificial lighting conditions, etc.)
- * Are you sure it is not possible to utilize existing airport and other radar systems and simply supply algorithms and software which would flag aircraft which are about to enter the area around each laser beam? [I verbally recommended this radar approach]
- * What is the maximum acceptable cost for each optical system?
- * What is the maximum acceptable size and weight?
- * How many optical systems will be deployed?
- * How soon will the first system be required?
- * What lead time is acceptable for additional systems?
(Intensified cameras and custom filters may be long lead items)
- * What environmental conditions will the system be exposed to?
- * How long will the systems be used? [Specifically,] how many years?
Seasonal or year round? How many hours per night?
- * How much training will the operators have?
- * What is the minimum elevation angle that can be reliably covered by the proposed [local] radar? What is the maximum range? How much does the optical detection area have to overlap the radar detection area?

[End of preliminary analysis. Jeffrey R. Charles]