and exposure time constraints for example, to protect a comprehensive range of existing services would be required. The LEO/MSS developers would then be able to determine their system parameters to meet these limits. The only other alternatives would be

(a) detailed coordination, which is inefficient for mobile services, or

(b) exclusive (worldwide?) assignments.

Fortunately, low transmit powers, message lengths, duty cycles, and traffic densities are consistent with the proposed LEO/MSS and, per the French analysis, the CDMA realization would appear to offer superior performance over the FDMA/FM realization. Thus the required sharing conditions should be viable for CDMA systems. Further study is required with respect to off-set carrier FDMA systems.

It was indicated previously that the most vulnerable existing service facility would be mobile base station receivers and that, in Canada, these stations would serve urban areas. The LEO/MSS location function would probably not be in high demand in urban areas so that this vulnerable exposure should have low probability of occurrence. This would leave the Fixed service serving rural areas as the main potential victims. The fixed service receiver does not need to be as sensitive as the mobile base station receiver and the FS antenna may have some directivity which would further limit the vulnerability.

On balance therefore, the interference potential from the uplink of a CDMA LEO/MSS into existing services may be reasonably handled with minimal restriction on the LEO/MSS transmit power and virtually no geographic constraints. The demands on the LEO/MSS intelligence would not be severe.

For a FDMA LEO/MSS in a shared band, the interference potential of the LEO/MSS, in terms of power density, the number of terminals that could exceed the interference threshold of the fixed or mobile receiver and the type and duration of interference, could be much higher placing extreme demands on the LEO/MSS system intelligence in order to protect existing services. A suggested alternative is to allocate a narrow band exclusively to the LEO/MSS. In support of this suggestion, it should be noted that the band 148.0 - 149.9 MHz is used by many safety and security services and that in these cases, while activity is often low for much of the time, when the services are required there would be a great sensitivity by the users to any level of detectable interference. From this point of view, the possible interference impact of an FDMA realization of the LEO/MSS could be more severe than the impact of a CDMA realization. In order to allay the concerns of present users of the band in the event of introducing the LEO/MSS, it would be instructive to investigate any measurement programs that demonstrate the interference impact of offset carrier narrow band signals and of low level spread spectrum signals on various conventional narrow band signals. Failing this, it should not be difficult to institute laboratory simulations. In the other direction, the immunity of spread spectrum signals to interference from narrow band signals is presumably well recorded.

It may be worthwhile to consider restricting the transmit powers of future implementations of existing services and even to re-examining some present high power installations in order to contain the interference into the LEO/MSS uplink. It would

appear, based on a very crude analysis, that a FDMA-LEO/MSS could have severe difficulty in the present environment while a CDMA-LEO/MSS could reasonably co-exist. This confirms the findings of the French paper.

Some possible alternative frequency allocations have been identified. These will be addressed in more detail in a separate study.

RECOMMENDATIONS

In summary, pending further study of these bands and assuming that offset operation of the FDMA version of the LEO/MSS is viable, the best alternative option for an uplink allocation at this time from a Canadian usage point of view would appear to be one of the bands 160 - 162 MHz, 166 - 168 MHz, or 167 - 169 MHz. These bands should be allocated to LEO/MSS on a non-interfering basis. These bands are less heavily used than the present proposal 148 - 149.9 MHz and apparently have no additional drawbacks. A 2 MHz allocation is suggested since the CDMA realization requires between 850 and 1000 kHz of contiguous spectrum and the FDMA realization requires at least 250 kHz that does not necessarily have to be contiguous and, according to the French analysis, the FDMA realization cannot share the CDMA spectrum. A wider allocation than the minimum required may ease sharing with existing services.

A reasonable compromise as a back-up option, pending further study of other alternate bands, would be to allocate LEO/MSS (E-s) on a non-interference basis in the presently proposed band 148.0 - 149.9 MHz (or some other 1 MHz band as indicated in the previous paragraph) and to replace Radionavigation Satellite in the band 149.9 - 150.05 MHz with LEO/MSS exclusive primary effective say 1995. This option would permit the CDMA realization in the shared part of the band and a slightly restricted FDMA realization (150 kHz instead of the recommended 250 kHz) in the exclusive part of the band. It may be possible to find or free-up an extra exclusive 100 kHz in nearby bands to meet the FDMA requirement. It is not necessary that this additional spectrum be contiguous with the 150 MHz band. It may not be necessary that this 100 kHz be common worldwide. However, in view of the beamwidth of the LEO satellite (Figure 2), a common allocation spanning a large area (multiple Administrations) would be required as a minimum. This solution maintains equipment commonality with existing broadcast receive antenna and permits both CDMA and FDMA realizations of the LEO/MSS.

The band 170 - 174 MHz and the band 216 - 220 MHz, while being reasonable candidates in Region 2 for allocation to the LEO/MSS, would not be suitable worldwide. The 400.15 - 401 MHz option is not viable from a technical/economic point of view.

K.Brown
September 11, 1991

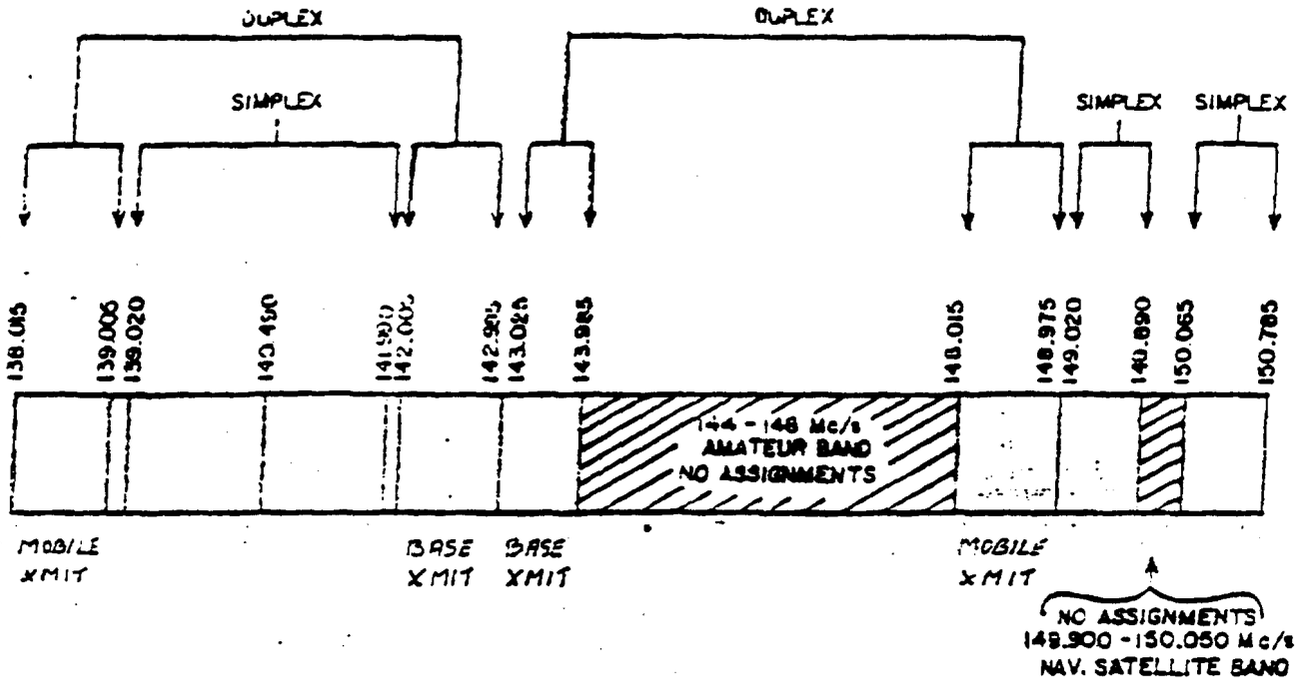

Figure 1: Canadian Assignment Plan for the band 138.005-150.785 MHz

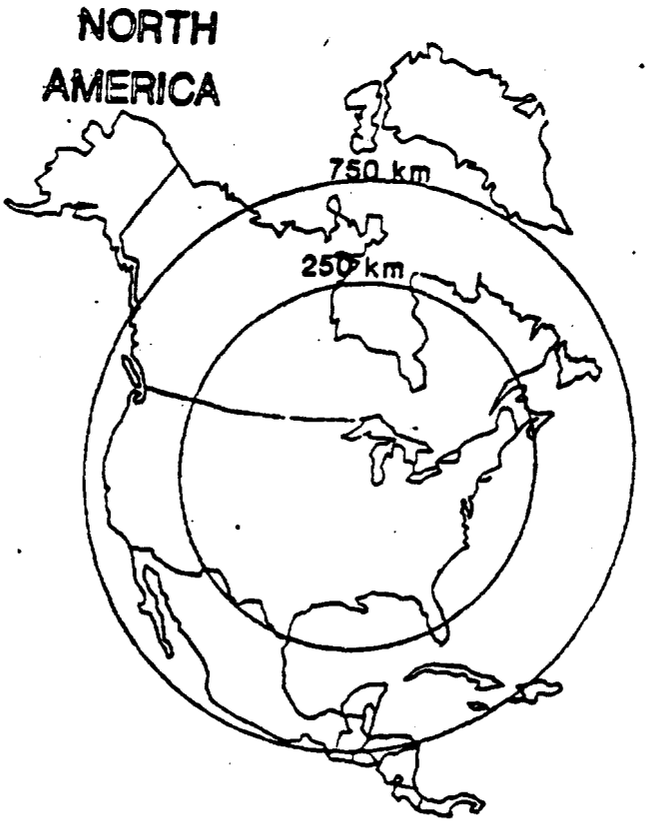

Figure 2: Example Visibility Areas of LEO Satellites

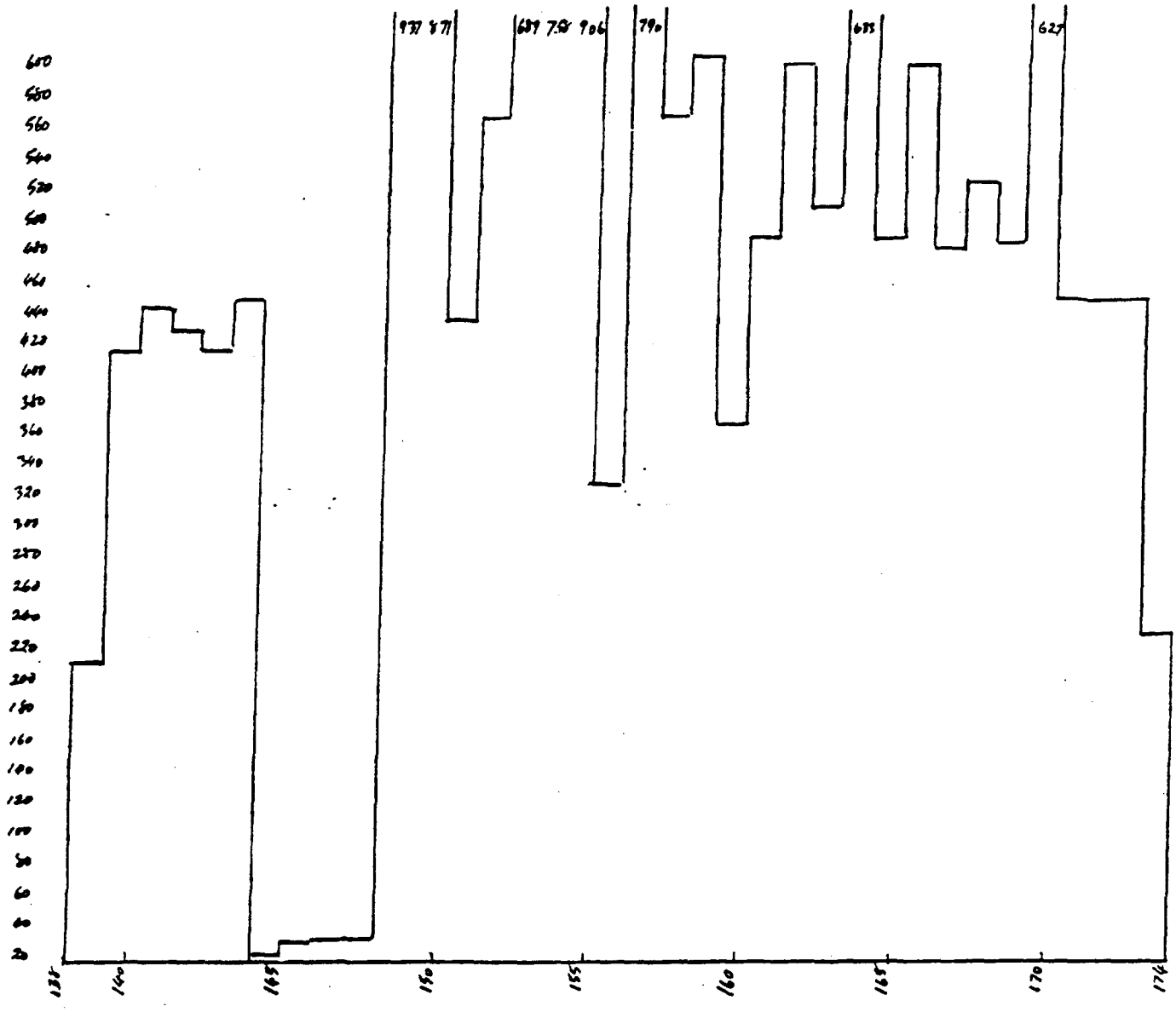

Figure 3: Number of Fixed Station and Base Station Licences per MHz in Toronto, Montreal and Vancouver (Sept.'91)

In view of the higher transmit powers, higher activity, and higher number of channels in the fixed and base stations compared to the mobile stations, only fixed and base station licences are considered. The band 144 - 148 MHz is allocated to AMATEUR, the band 155 - 156 MHz contains the MARITIME MOBILE international distress and safety band 156.7625 - 156.8375 MHz. The 170 - 174 MHz band is allocated to BROADCASTING in several countries and is adjacent to BROADCASTING in all Regions.

References:

1 "Utilization of the Band 148-149.9 MHz: An Overview of the Interference Potential to Low Earth Orbit Satellite Services" TN-110, J-C Brien, July'91.

2 Annex 2 of Position Paper from France; "Criteria for the Sharing of Systems to Communicate Between Mobile Terminals and Low Earth Orbiting Satellites in Frequency Bands Below 1 GHz"

3 JIWP Report Table 11-I

4 CCIR SG VIII Report 358-5; "Protection Ratios and Minimum Field Strengths Required in the Mobile Services"

5 CCIR SG V Report 567-3; "Methods and Statistics for Estimating Field-Strength Values in the Land Mobile Services Using the Frequency Range 30 MHz to 1 GHz"

6 Policy Manual, PM-1 Rev 57, Dec.'82

APPENDIX 1: PARAMETRIC MODEL

A refinement of the gross estimate of interference power received by a LEO satellite is presented. This model might permit some parametric studies but, short of a detailed coordination exercise taking account of exact locations and individual transmit powers, antenna characteristics and channel activity, any such model is heavily dependent on simplifying assumptions for these parameters so that it can only be considered as a qualitative assessment at best. In view of this, the model has not been developed beyond the mathematical formulation.

Assumptions

1. uniform geographic distribution of fixed and mobile transmissions across visible area;
2. uniform distribution of fixed and non-paging mobile transmission channels across the given spectrum;
3. all transmissions (fixed and mobile) are omnidirectional in the horizontal plane;
4. all transmissions employ the same average transmit powers, antenna characteristics, and activity and loading factors;
5. there is 3 dB polarization discrimination between LEO satellite uplink (circular) and terrestrial (horizontal or vertical) transmissions;
6. interference paths are limited to within the geometric horizon from the satellite.

Geometry

Per Figure A-1, consider a triangle 'SOP' where 'S' is the LEO satellite at a typical point on the orbit, 'O' is the centre of the earth, and 'P' is an arbitrary point within the visibility area of the satellite. Define ∠SOP as θ, ∠OSP as ϕ, and ∠OPS as $90 + \epsilon$ (ϵ is the elevation angle to the satellite). Let radius of earth (OP) be 'R', height of satellite (OS - R) be 'h', path length (SP) be 'x'. Maximum value of θ is Θ and of ϕ is Φ which occur when ϵ is zero;

$$\Theta = \cos^{-1}\{R/(R + h)\}, \qquad \Phi = \sin^{-1}\{R/(R + h)\}$$

Solving triangle SOP:

$$x(\theta) = \sqrt{\{R^2 + (R + h)^2 - 2 * R * (R + h) * \cos(\theta)\}}$$

$$\phi = \sin^{-1}\{R * \sin(\theta)/x\}$$

$$\epsilon = \cos^{-1}\{(R + h) * \sin(\theta)/x\}$$

The mean squared path length is obtained by multiplying the annular area at 'P' subtended by $\delta\theta$, radius $R * \sin(\theta)$ by x^2 and integrating over the interval $\theta = 0$ to Θ

and then dividing by the area of the cap. Thus, the ratio of mean squared path length to squared height is:

$$\frac{x'^2}{h^2} = \frac{\int_0^{\Theta} x^2 * \sin(\theta)\, d\theta}{h^2 * \int_0^{\Theta} \sin(\theta)\, d\theta} = \frac{R + h}{h}$$

The angles θ', ϕ' and ϵ' at which this mean path occur are found from above.

Examples:

a) $R = 6378$ km, $h = 250$ km, $R + h = 6628$ km

$x_{max} = 1803$ km

$\Theta = 15.8°$ $\Phi = 74.2°$

$x' = 1287$ km

$\theta' = 10.7°$, $\phi' = 66.9°$, $\epsilon' = 16.4°$

b) $R = 6378$ km $h = 750$ km, $R + h = 7128$ km

$x_{max} = 3183$ km

$\Theta = 26.5°$ $\Phi = 73.5°$

$x' = 2312$ km

$\theta' = 18.7°$, $\phi' = 62.0°$, $\epsilon' = 9.3°$

Aggregate Interference Power

Under assumption 1, the number of transmitters at elevation angle ϵ is proportional to the area of the annulus on the earth's surface formed when a small arc $\delta\theta$ at 'P' is rotated about 'OS', i.e.

$$n(\theta) = \frac{N * \pi * \sin(\theta + \delta\theta/2)}{180 * (1 - \cos(\Theta))}$$

where N = number of transmitters in the frequency band of interest taking account of Assumption 2, i.e., for the narrow band encompassing the heavily used paging channel 149.77 MHz, $N = 328 + 0.4 * (8780 - 751)/61 \approx 380$ as in the main text,

θ and $\delta\theta$ are in degrees

If it is assumed that both the satellite and the terrestrial mobile base station antennae have off-axis gain characteristics decreasing as the square of the off-axis angle (see, for example, Scala OG-4 series 4 dBi antenna, 3 dB vertical beamwidth ± 15° approximately), the power received at the LEO/MSS satellite due to transmitters at points 'P' before taking account of polarization discrimination is then;

$$p(\theta) = n(\theta) * E * (c/4\pi.f.x(\theta))^2 * (k_{sat1}(\exp(-k_{sat2}\phi^2))) * (k_{ter1}(\exp(-k_{ter2}\epsilon^2)))$$

where: E is the average transmit erp
c is the velocity of light
f is the frequency
$k_{sat1,2}$ and $k_{ter1,2}$ are constants defining the antennae discrimination

This expression in θ is a bit messy to integrate; therefore assume δθ is 1° and sum individual contributions:

$$p_{tot} = \sum_{\theta=0}^{[\theta - 0.5]} p(\theta)$$

is the total interference power received at the satellite before polarization discrimination (square brackets indicate 'integer part of').

Then;

$$P = 10 * \log_{10}(p_{tot}) - 3 \qquad \text{dBW}$$

As indicated above, there are a number of fundamental assumptions embedded in this result.

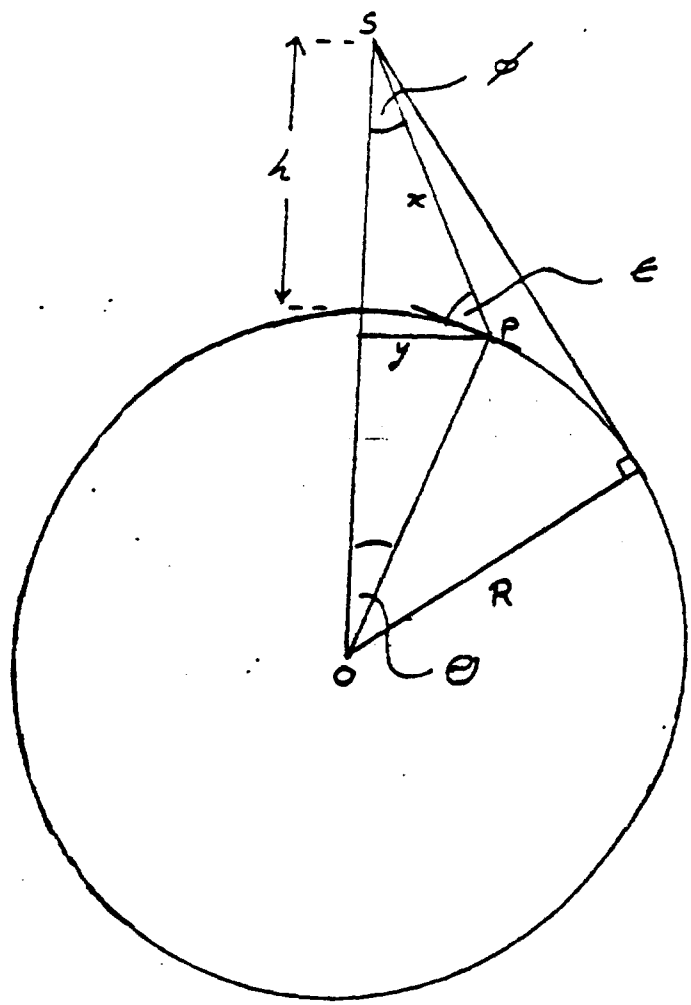

Figure A-1: Geometry for Interference Model

SCHEDULE
INFORMAL WORKING GROUP
Below 1 GHz LEO Negotiated Rulemaking Committee

Wed., August 12 -- 9:00-12:00 at 2000 K
Thu., August 13 -- 10:00-12:00 at 2000 L
Fri., August 14 -- 1:00-4:00 at 2000 L

Mon., August 17 -- 9:30-12:00 at 2000 K
Tue., August 18 -- 9:30-12:00 at 1919 M (Full Committee)
Wed., August 19 -- 9:30-12:00 at 1919 M
Thu., August 20 -- 9:30-12:00 at 1919 M
Fri., August 21 -- 9:30-12:00 at 1919 M

Mon., August 24 -- 9:30-12:00 (Full Committee), 1:00-4:00 (IWG) at 1919 M
Tue., August 25 -- no meeting
Wed., August 26 -- no meeting
Thu., August 27 -- no meeting
Fri., August 28 -- no meeting

Mon., August 31 -- no meeting
Tue., September 1 -- 9:30-5:00 at 1919 M (Full Committee)
Wed., September 2 -- 2:00-4:00 at 1919 M
Thu., September 3 -- 9:30-12:00 at 1919 M
Fri., September 4 -- 9:30-12:00 at 1919 M

Meeting Rooms: 2000 K -- Suite 600
2000 L -- Training Room, 2nd Floor
1919 M -- Rm. 856

STATEMENT OF LEOSAT CORPORATION TO THE BELOW 1 Ghz NEGOTIATED RULEMAKING COMMITTEE

AUGUST 18, 1992

LEOSAT entered into these negotiations in a spirit of good faith. It recognized from the outset that much of what it would be asked to do by the FCC would not be in its own private best interest, but the interest of the general public and future competitors. Such is the nature of a negotiated rule making. The applicants are not here to defend their applications -- submitted two years ago -- but to propose rules that they and future applicants can live by. To do otherwise would undermine the legitimacy of this innovative process and ensure a challenge to these rules. Unfortunately, to date the Committee has not moved beyond the narrow interests of the private sector parties in considering sharing rules.

On August 7, 1992, the eve of these negotiations, ORBCOMM, STARSYS and VITA submitted Supplemental Comments in Docket 92-76 in which they proposed a technical sharing plan for the spectrum considered for allocation in Docket 91-280. They have elaborated on this plan in recent days. LEOSAT respectfully submits that this plan is nothing more than a blatant attempt to impose through a private technical settlement a roadblock to future competition. These parties say as much by noting that their proposal is intended to resolve the mutual exclusivity between them to permit the FCC to license them without a hearing. Supplemental Comments at 2. It is for the Commission to establish the appropriate number of LEO providers, not the existing applicants through the use of a settlement that adopts an inefficient modulation technique. This Rule making Committee has been tasked with establishing the theoretical "envelope" for multiple providers -- not one that suits only the current applicants.

Despite the fact that the parties knew that LEOSAT was a party to the rule making, LEOSAT was never invited to join the discussions. More importantly, the sharing plan was finalized and submitted in direct contravention of the FCC's explicit direction of April 16, 1992, tasking the Committee to determine "the extent to which the spectrum may be shared by future applicants." Public Notice in CC Docket No. 92-76. At the time of this statement, the Commission had four (4) valid applications before it. Thus, we can only assume that the minimum number that this negotiation must seek to technically accommodate is five (5).

Several times in the last week LEOSAT has called upon the parties to allow their engineering experts to develop a joint sharing plan that would meet the needs of future applicants. LEOSAT renews that invitation today. We have heard that it is not the responsibility of these private parties to provide for future sharing. On the contrary, this is the explicit direction of the Commission. We have heard that it is not for the parties to suggest the appropriate modulation scheme. On the contrary, the Commission directed the parties to determine "which modulation method should be employed by the parties in order to co-exist with other satellite and terrestrial systems in the band." Public Notice in CC Docket 92-76. As the parties recognize, these are difficult issues that will require good faith accommodations. But it is not enough to stand by whatever modulation scheme is in that party's application or one in which that party has invested significant resources. That would make a mockery of these negotiations and ensure that the Commission does not receive the best possible advice.

Today, LEOSAT is submitting a working document for consideration of the Committee that discusses the benefits of CDMA versus FDMA. LEOSAT also notes that STARSYS -- until its recent sharing arrangement with ORBCOMM and VITA -- was an enthusiastic proponent of CDMA. As recently as December 1991 STARSYS stated that "the Commission's multiple entry policy is possible only if spread spectrum operation is required for the LEO satellite services. Spread spectrum operation affords the Commission greater flexibility in allocation schemes, and will allow as many as seven systems to share the same one megahertz of spectrum with greater system efficiency than is achievable with even one frequency division multiple access system." STARSYS Comments in E.T. Docket 91-280 at vii-viii. In the excerpt from its 1991 comments distributed to the Working Group just yesterday, STARSYS claimed that CDMA spread spectrum modulation is more efficient than FDMA modulation and should be required. Id. at 39.

LEOSAT is left to wonder what -- other than a desire to limit the number of competitors to less than seven -- is behind STARSYS' disavowal of the technically optimal CDMA alternative. We look forward to exploring this in future working group meetings. This is not to say that CDMA is the only solution. Only that at least two parties are on record for the use of full CDMA. The Commission should wonder why it is now confronted with an FDMA/CDMA sharing plan that can accommodate only three (3) competitors.

All of this is not meant to be a criticism of ORBCOMM, STARSYS, VITA or the FCC staff. Rather, we mean it to be a call to action. This process is a "first" for both the parties and the FCC staff. The concept of proposing rules and technical standards that could benefit potential competitors is certainly unique for all of the private sector parties. And allowing applicants to do so must leave the FCC staff with a queasy feeling.

The Commission's mandate is -- to say the least -- challenging. And our time to fulfill it is extremely short. LEOSAT is ready, willing and able to work with its competitors to complete the task. Lets demonstrate that private interests can be melded with the public good!

AGENDA
BELOW 1 GHz LEO NEGOTIATED RULEMAKING COMMITTEE
August 18, 1992

1. Approval of agenda
2. Opening remarks
3. Approval of minutes
4. Election of Co-Facilitator
5. Identification of additional record information
6. Report on progress of informal working group
7. Discussion of additional/revised tasks, if any, for informal working group (Work program - LEOAC-2 (Rev.1))
8. Update agenda for next meeting
9. Other business

TENTATIVE AGENDA
BELOW 1 GHz LEO NEGOTIATED RULEMAKING COMMITTEE
August 24, 1992

1. Approval of agenda

2. Opening remarks

3. Approval of minutes

4. Consideration of Co-Facilitator

5. Identification of additional record information

6. Report on progress of informal working group

7. Discussion of informal working group reports

8. Discussion of additional/revised tasks, if any, for informal working group (Work program - LEOAC-2 (Rev.1))

9. Formation of informal editorial working group to prepare the Committee's report to the Federal Communications Commission

10. Agenda for next meeting

* 11. Presentation(s) by LEO systems proponents with regard to views on sharing in the allocated bands

12. Other business

* This item may be presented earlier in the agenda.