1. Introduction and Summary

The Environmental Management of the Space and Missile Systems Center (SMC) has set out to evaluate the depletion of stratospheric ozone caused by Air Force activities in space. Recent work supported by SMC included an assessment of the impact of deorbiting debris on stratospheric ozone (Ref. 1.1) and the potential for reduction of ozone destruction by use of alternate propellants for launch vehicle rocket engines (Ref. 1.2). A key goal of the SMC effort is to upgrade requirements for the prototype high-resolution ozone imager (HIROIG) (Ref. 1.3). The present work provides inputs for further HIROIG requirement resolution. It addresses the effects of rocket exhaust on stratospheric ozone. The local, short time, effect (as measured by HIROIG) is evaluated as is the ultimate global effect. Consideration of both short time and global effects enable connection of launch predictions and measurements of ozone depletion to the ultimate, long term depletion of stratospheric ozone. The present effort extends the work reported in Reference 1.4 in which a methodology was described which allows a quantitative assessment of the impact on stratospheric ozone by rocket exhaust.

The primary results of the present study are summarized as follows:

1) A validated methodology has been established. Kinetics and diffusion model upgrades (inclusion of NO, chlorine, and heterogeneous mechanisms; diffusion

model validated and anchored to in situ data) have been applied to a TITAN III launch for which in situ measurements of ozone depletion are available. Good comparison with this data provides a validation of the present methodology.

2) Analysis of the SRM-induced depletion of ozone during a TITAN III launch was addressed. Local ozone depletion is presented: the HIROIG sensor can be expected to view a local ozone hole of several kilometers radius and of duration from ten minutes to nearly an hour after launch. It needs to take into account possible polarization effects caused by alumina particle formation. This can be achieved by using three identical sensors sensitive to light polarized in different planes. Details of the configuration are provided in Chapter 6. Extension to post-launch times is discussed.

3) Loss of stratospheric ozone loss caused by liquid rocket engine boosters is evaluated (the primary loss is caused by nitric oxide). The effects are insignificant when compared to SRM boosters. Two considerations lead to this conclusion:

i) The NO catalytic cycle mechanism causes less ozone destruction than that of chlorine. Furthermore, present liquid boost engines (RP-1/LOX; LH_2/LOX) are not nitrogen-based thus leaving afterburning as the only process by which NO can be produced. Afterburning in the stratosphere produces very little nitric oxide.

ii) Presently, all large-thrust U.S. launch vehicles are chlorine-based SRMs that are capable of producing large amounts of chlorine in the boost phase.