OVERVIEW OF HLLV EFFLUENTS IN STRATOSPHERE AND ABOVE

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The single most important SPS-related cause of large-scale upper atmospheric effects is the injection of large quantities of rocket exhaust effluent into atmospheric regions in which the exhaust products are naturally present only in trace quantities. Of the four vehicles involved, the heavy lift launch vehicle (HLLV) is by far the most important source of exhaust effluent in the region between the Earth's surface and low-Earth orbit (LEO). This discussion provides an overview of HLLV emissions and the corresponding potential atmospheric effects.

The factors which make the HLLV so important are the unprecedented size (400 ton payload) and launch frequency (375 or more flights/year). In combination, these factors imply that an unprecedented quantity of exhaust products will be emitted. Due to the choice of fuels for the first and second stages, the main exhaust products below the staging altitude of 56 km are CO_2 and H_2O, and H_2O and H_2 above that altitude. In addition, there will be small amounts of CO, H_2 and NO deposited below 56 km and a significant amount of NO deposited during second-stage reentry between 60 and 90 km. Most of the second-stage exhaust emissions take place between 110 km and 125 km, because of the particular trajectory chosen.

Injections of exhaust effluent into the stratosphere by the first stage is not expected to have any detectable effects; the projected exhaust emissions give rise to concentration changes which are orders of magnitude smaller than existing levels even for "trace" substances like water and the nitrogen oxides.

Injections of water and molecular hydrogen by the HLLV second stage in the mesosphere and lower thermosphere may give rise to a variety of effects. Table 1 summarizes these emissions. It is expected that an artificial noctilucent cloud will be produced following each launch, and that such a cloud will persist for several hours at least, but probably not as long as a day. Upward diffusion of H_2O and H_2 and the downward motion of the exhaust cloud from the circularization burn are expected to cause some temporary depletion of the plasma density in the F-region of the ionosphere. Reentry-produced nitric oxide will persist within a more or less localized region for perhaps 1-2 days. In addition, global, long-term effects must be considered, especially in view of the high launch frequency. Theoretical calculations indicate that the global average water concentration at the mesopause will increase by about 1%, with an increase on the order of 15% near the launch latitude. The hemispheric average integrated ozone column density is expected to decrease by approximately 0.03%. No long-term accumulation of noctilucent clouds is expected. Figure 1 shows the result of a simple calculation of the steady-state global average increase in the water concentration as a function of altitude. The treatment of chemistry was considerably simplified and the figure should be considered as providing a rough estimate only and not necessarily as quantitatively correct. The effect of the reaction between water and oxygen ions at around 250 km can be clearly seen as a broad depression in the curve. These calculations yield water concentrations of 0.1 ppmV at 90 km, 8 ppmV at 120 km, 4 ppmV at 150 km and 0.5 ppmV at 200 km.

Figure 2 shows the result of a similar calculation for molecular hydrogen. Again, the effects of reaction with oxygen ions can be clearly seen.

Finally, based upon an injection rate of 2×10^{33} NO molecules/year due to reentry in the region from 60 to 90 km, an ambient loading of 4.7×10^{32} molecules and an approximate residence time of 4 days, the expected increase in the steady-state, globally averaged mesospheric NO concentrations is estimated to be **4%**.

Table 1

HLLV INJECTIONS ABOVE 56 KM

Burn	Altitude (km)	Magnitude/flight (metric tons) Water	Hydrogen
Main	56-125	2210	80
Circ.	477	20	0.7
Deorbit	477	11	0.4
Reentry	60-90	300 (NO)	

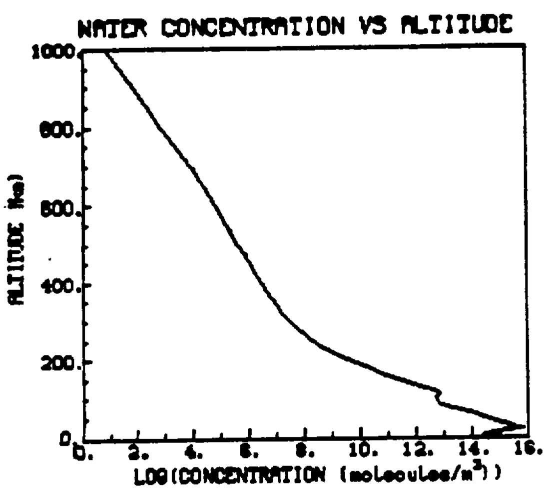

Figure 1

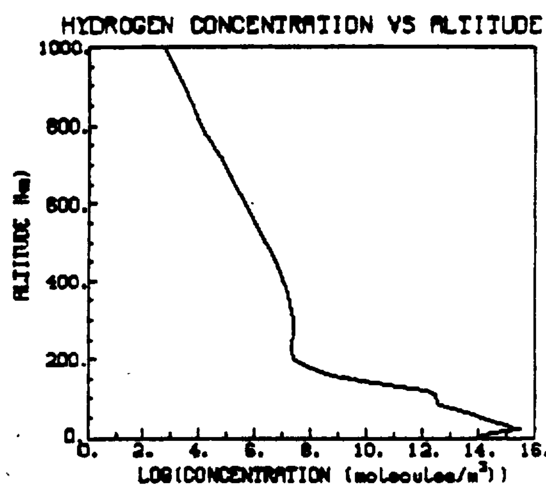

Figure 2