Fact Sheet:

Regarding Assumptions Used in the *Geophysical Research Letters* Paper Titled "Potential Climate Impact of Black Carbon Emitted by Rockets"

- Each of the planned commercial suborbital vehicles has differing combinations of flight profile, anticipated flight rate, and propulsion technology. This means that the specific and idealized assumptions inherent in the Ross et al. study cannot be extended to include the general class of commercial suborbital vehicles.

- As stated in Ross et al., there are many unknowns related to the microphysical properties of the exhaust particles, including size, structure, composition, and coagulation rates. Accordingly, the range of uncertainty in the models could be large and such ambiguities could significantly change the magnitude of the results, yet the paper includes no estimate of margin of error or a range of values for their findings.

- The Ross et al. (2010) research paper assumes 10,000 kg of propellant per launch, but this is well in excess of the propellant load for most suborbital vehicles. For example, Virgin Galactic's SpaceShipTwo only has a 6,600 kg propellant load.

- For liquid oxygen/kerosene engines, Ross et al. assumes that they produce 20-40 grams of soot per kilogram of propellant. The lower value of 20g/kg is derived from measurements of an obsolete launch vehicle with 1950's engine technology. A review of the modern literature, including Rocket Exhaust Plume Phenomenology (Simmons, 2010), suggests that modern engines, which use more oxygen and less fuel, should be an order of magnitude cleaner.

- Ross et al. reports the results of modeling of complex propulsion phenomena and the interaction and effects of propulsion systems on our complex atmosphere. While modeling can serve as a guide to potential effects, only the actual observation of such effects during ground and flight-testing can deliver definitive results regarding environmental impacts, whether large or small.

- It is not yet clear whether Ross et al. included in their analysis the carbon particles present in the stratosphere from various sources, including natural processes such as meteorite dust. Estimates by the Intergovernmental Panel on Climate Change (IPCC), a scientific intergovernmental body of the United Nations, of the quantity of soot already in the stratosphere are many times greater than the hypothesized emissions assumed by Ross et al.