# Rockets in the Stratosphere

by GWYNNE DYER

If you're worried about your ?carbon footprint? ? a concept foisted on the world in 2004 by British Petroleum to persuade people that their own behaviour, and not giant oil companies like BP, is causing the climate problem ? then you definitely should not sign up for a sub-orbital space flight. Besides, you probably can't afford it ($250,000 pp).

Millions of people can afford it, however, and since the Branson/Bezos ?space race? last month, tickets for sub-orbital flights are selling fast. These are commercial ventures, after all.

There are only three more flights scheduled for Jeff Bezos's ?Blue Origin? rocket before the end of the year, and two more for Richard Branson's ?VSS Unity?, but both men clearly intend to ramp up to more frequent flights. (Branson predicts 400 flights a year)

The era of mass space tourism is just around the corner.

Well, what did you expect? The travel and tourism industry accounted for 10.7% of world GDP in the last normal year (2019), so nowhere is safe, including the stratosphere. And like every other tourist destination, the stratosphere suffers some environmental damage from all the tourists passing through.

The key question, so far unanswered, is: how much?

Hardly any at the moment. The typical rocket launch dumps the same amount of CO2 into the atmosphere as one airliner does in the course of a trans-Atlantic crossing. Since there are only three or four passengers aboard each of those sub-orbital flights, their individual carbon footprints are huge ? but more than 1,700 commercial jets cross the Atlantic on the average day.

Most rockets, including Elon Musk's ?Falcon Heavies? and most of the big Chinese and Russian vehicles, burn a mixture of kerosene and liquid oxygen and produce an exhaust plume little different from that of jet aircraft: mostly carbon dioxide and water. But the total fuel used annually by all the world's rockets is less than one percent of that burned by commercial aircraft.

Moreover, some of the newer rockets, like Bezos's ?New Shepard?, most European launch vehicles, and the last stage of the new Long March rockets, use Liquid Hydrogen and Liquid Oxygen, which leaves only water and a few traces of other chemicals. So far, so relatively harmless ? except that all the other rockets leave black carbon (?soot?) in the upper stratosphere, where airliners don't fly.

The commercial aircraft do leave soot in the lowest part of the stratosphere, where its effects are reasonably well understood. It warms the lower stratosphere. It presumably does that in the upper parts of the stratosphere too, but we have little information about how that impacts the global climate, if indeed it has any discernible effect at the volumes currently being deposited there by rockets.

The annual orbital rocket traffic is surprisingly low: a record 1,283 satellites were put into orbit last year, but only 104 rocket launches were used to put them there. (Another ten launches were failures, but failures tend to happen before rockets reach the stratosphere.) This means the prospective ?tourist? launches represent a four- or five-fold jump in the stratospheric traffic.

Bezos's launches get a pass because he's not burning kerosene and leaving soot behind. Branson's rocket, however, is powered by a ?hybrid engine? that burns hydroxyl-terminated polybutadiene (synthetic rubber), with nitrous oxide as an oxidiser. You can think of it as a soot generator with stratospheric capability. And 400 flights a year.

So, the Branson rocket should be closely monitored for its impact on the stratosphere, and how that might affect the climate. The

impact could be insignificant, but it will be a much bigger contributor to stratospheric pollution than its size suggests. And what of space flight in general?

There will certainly be more orbital flights as time goes on, but most satellites are now very small packages that can be packed together on a single launch. Moreover, there is a clear move towards using liquid hydrogen rather than kerosene as a fuel, despite hydrogen's current high price, and a longer-term aspiration to use high-energy biofuels that are carbon-neutral.

Aviation as a whole remains a significant part of the warming problem, producing more than 3% of global CO2 emissions, and the solutions are expensive or technically difficult. Biofuels can eventually address the carbon dioxide emissions, but at least half the aviation-linked warming is not CO2. Its heat reflected back to the ground by contrails.

The remedy for that is to fly in the lower atmosphere, where contrails rarely form ? but that puts planes back down in the turbulence, which passengers do not like. Planes could be designed that would counter that turbulence (ducted flow and computer-driven instant response), but there's no sign of it yet.