How Should Scatterers Be Deployed? There are three obvious choices for deployment-sites for scatterers on scales of interest for insolation modulation.[15] One is the terrestrial stratosphere, the second is in a low-Earth orbit (i.e., an orbit whose radius may be as much as twice the radius of the Earth), and the third is a position along the line between the centers of the Earth and the Sun (approximately one hundred times the Earth's radius distant from the Earth).

Of the three deployments, the stratospheric location is by far the least expensive on a pound-for-pound basis; positioning mass in the stratosphere currently is at least 10^4 times less costly than putting it into low Earth orbit.[16] Moreover, the mid-stratospheric residence time of sub-

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that this average (optical-frequency) current density-per-gram metric permits the comparison of metallic, dielectric and atomic-resonant scattering materials, moreover in a manner independent of particular scattering system geometry. It merely looks at the quantity which scatters the sunlight's optical field: the space- and time-averaged current density driven up by the electric fields of the solar photons in the matter constituting the *scattering unit*, and the outgoing-wave optical-frequency fields which this density generates.

Most dielectric materials of interest have optical dielectric coefficients $\varepsilon \leq 2$, and we generally must consider $(\varepsilon-1)\leq 9\times10^{-13}$ farads/cm. Available metals (e.g., Al) have electrical resistivities $\geq 3\times10^{-6}$ ohm-cm (taking some degradation from best bulk properties for very thin layers), i.e., conductivities $\sigma\leq 3\times10^{5}$ mho/cm. Optical frequencies of resonant transitions are $\sim10^{15}$ Hz, and these transitions correspond to electron travel over orbital distances ~3 Å, i.e., across atoms of ~3 Å diameter. Take a reference mid-visible optical angular frequency of $\sim4\times10^{15}$ sec^{-1}. Then the optical current density I in a unit volume (whose greatest dimension is assumed to be $\leq\lambda/2\pi$) of such a dielectric at unit electric field strength is $I\sim E/Z\sim\omega C$, or $4\times10^{15} \times 9\times10^{-13}$, or 3.6×10^{3} amp/cm^2. The current density in the same circumstances in a good metal is just $I\sim\sigma E\sim\sigma$, or 3×10^{5} amps/cm^2. Unit optical electric field strength of 1 V/cm corresponds to an optical flux of 10^{-4} W/cm^2, so that sunlight's intensity at 1 AU of 0.1 W/cm^2 implies a mean frequency-averaged optical electric field of ~30 V/cm. This optical field strength will drive ~30 transitions/sec in a typical full-strength-dipole atomic oscillator, as noted above; unit optical electric field strength thus will drive $\sim3\times10^{-2}$ transitions/second in such an atom. Each atom is assumed to occupy a volume of $\sim3\times10^{-23}$ cm^3, so that $\sim10^{21}$ transitions/sec are driven by a unit-strength solar-spectral optical electric field in a cm^3 volume of such material. Each such transition corresponds to a optical-frequency current of a single electron's charge – 1.6×10^{-19} coulombs – moving through a distance $\sim3\times10^{-8}$ cm every $\sim10^{-15}$ sec. This corresponds to a optical frequency current density of $\sim5\times10^{9}$ amp/cm^2 (!).

For constituting *scattering units*, then, the relative figures-of-merit of best-available dielectrics, metals and resonant-scatterers are roughly $1:10^2:10^6$.

[14]The "packaging mass overhead" for quasi-resonant scatterers typically is much larger than that for metallic and dielectric scatterers, so that much of the former's huge intrinsic mass advantage is lost in scattering systems prepared for multi-year durability-in-service.

[15]The Earth's surface is not considered for reasons of land-use and local microclimate impacts, while the ocean surface poses stability/durability/navigation compatibility concerns, and tropospheric residence times are not usefully long for the types of scattering systems which we consider.

[16]We estimate a total cost of lifting mass into the stratosphere on wide-body commercial aircraft to be ~$0.3/pound, whereas the current cost of putting a pound-mass of payload into low Earth orbit by