In this work we study exact spacetimes that represent the gravitational field of a localized object accelerating due to an anisotropic emission of photons – photon rocket. First, we describe general properties of the Kinnersley and the Bonnor rocket, which both belong to the family of Robinson–Trautman spacetimes. Subsequently, we summarize two main approaches to the study of asymptotically flat spacetimes: the Bondi–Sachs and the Penrose methods, combined and modified by Tafel and Pukas in recent papers. We compare the mass aspect of the Robinson–Trautman spacetime obtained by both methods, and generalize thus the relation found by von der Gönna and Kramer. Next, we calculate the energy-momentum vector, the Bondi rest mass, and the „news tensor“ for the arbitrarily moving Kinnersley rocket. By using these results, we naturally define the velocity vector of the rocket with respect to the Minkowski „background“ spacetime. We conclude with the physical interpretation of the Kinnersley rocket in various reference frames.