Abstract: Orbital, spin and astrometric parameters of the millisecond pulsar PSR J0621+1002 have been determined through six years of timing observations at three radio telescopes. The chief result is a measurement of the rate of periastron advance, $\dot{\omega} = 0.00116 \pm 0.00008 \text{ yr}^{-1}$. Interpreted as a general relativistic effect, this implies the sum of the pulsar mass, $m_1$, and the companion mass, $m_2$, to be $M = m_1 + m_2 = 2.81 \pm 0.30 M_\odot$. The Keplerian parameters rule out certain combinations of $m_1$ and $m_2$, as does the non-detection of Shapiro delay in the pulse arrival times. These constraints, together with the assumption that the companion is a white dwarf, lead to the 68% confidence maximum likelihood values of $m_1 = 1.70^{+0.32}_{-0.25} M_\odot$ and $m_2 = 0.97^{+0.27}_{-0.15} M_\odot$ and to the 95% confidence maximum likelihood values of $m_1 = 1.70^{+0.59}_{-0.63} M_\odot$ and $m_2 = 0.97^{+0.43}_{-0.24} M_\odot$. The other major finding is that the pulsar experiences dramatic variability in its dispersion measure (DM), with gradients as steep as 0.013 pc cm$^{-3}$ yr$^{-1}$. A structure function analysis of the DM variations uncovers spatial fluctuations in the interstellar electron density that cannot be fit to a single power law, unlike the Kolmogorov turbulent spectrum that has been seen in the direction of other pulsars. Other results from the timing analysis include the first measurements of the pulsar’s proper motion, $\mu = 3.5 \pm 0.3 \text{ mas yr}^{-1}$, and of its spin-down rate, $dP/dt = 4.7 \times 10^{-20}$, which, when corrected for kinematic biases and combined with the pulse period, $P = 28.8\text{ ms}$, gives a characteristic age of $1.1 \times 10^{10} \text{ yr}$ and a surface magnetic field strength of $1.2 \times 10^{9} G$. 
