

$$\frac{d}{dt} \underbrace{{}_s \mathcal{H}^t \times \mathcal{Q}^t}_{\text{}} = {}_s \mathcal{H}^t \times \left( \frac{d}{dt} \mathcal{Q}^t + X^t \times \mathcal{Q}^t \right) = {}_s \mathcal{H}^t \times \left( \frac{d}{dt} \mathcal{Q}^t + \iota_{X^t} \underbrace{d\mathcal{Q}^t}_{\text{}} + d \iota_{X^t} \overbrace{\mathcal{Q}^t}^{\text{}} \right)$$