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# THERMODYNAMICS AND LARGE-SCALE NONLINEAR DYNAMICAL SYSTEMS: A VECTOR DISSIPATIVE SYSTEMS APPROACH

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**Abstract.** Recent technological demands have required the analysis and control design of increasingly complex, large-scale nonlinear dynamical systems. In analyzing these large-scale systems, it is often desirable to treat the overall system as a collection of interconnected subsystems. Solution properties of the large-scale system are then deduced from the solution properties of the individual subsystems and the nature of the system interconnections. In this paper we develop an energy flow modeling framework for large-scale dynamical systems based on *vector dissipativity* notions. Specifically, using vector storage functions and vector supply rates, dissipativity properties of the composite large-scale system are shown to be determined from the dissipativity properties of the subsystems and their interconnections. Thermodynamic principles are also established using a large-scale systems perspective.

**Keywords.** Vector dissipativity theory, vector storage functions, vector supply rates, vector Lyapunov functions, thermodynamic modeling, energy flow, energy equipartition, entropy, ectropy, stability, semistability

**AMS (MOS) subject classification:** 80A05, 80A20, 90C06, 34D20, 34D35, 37B25

# 1 Introduction

Modern complex dynamical systems[1] are highly interconnected and mutually interdependent, both physically and through a multitude of information and communication network constraints. The sheer size (i.e., dimensionality) and complexity of these large-scale dynamical systems often necessitates a hierarchical decentralized architecture for analyzing and controlling these systems. Specifically, in the analysis and control-system design of complex large-scale dynamical systems it is often desirable to treat the overall system as a collection of interconnected subsystems. The behavior of the aggregate

[1]Here we have in mind large flexible space structures, aerospace systems, electric power systems, network systems, economic systems, and ecological systems, to cite but a few examples.