

Modeling and Valuing Cogeneration

RCS

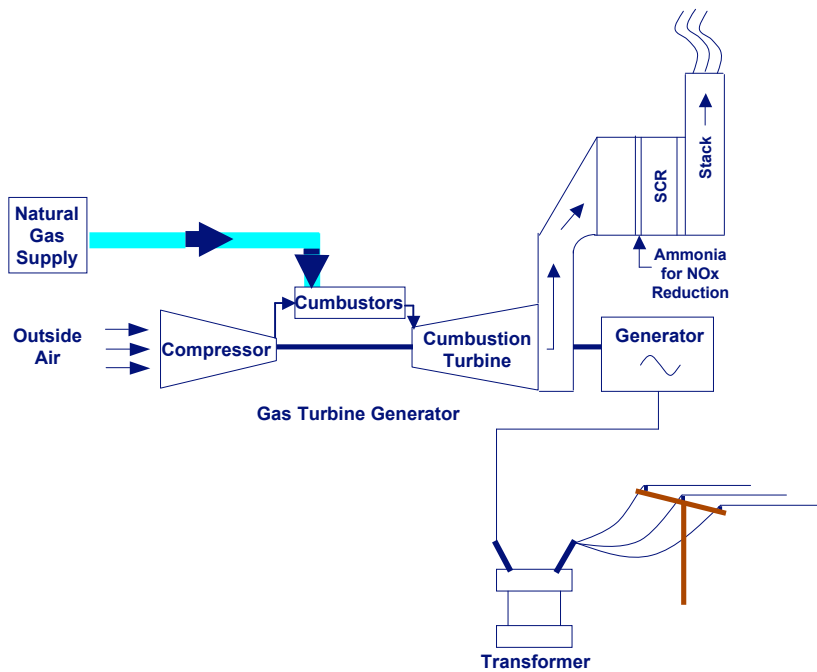
Ray Bliven

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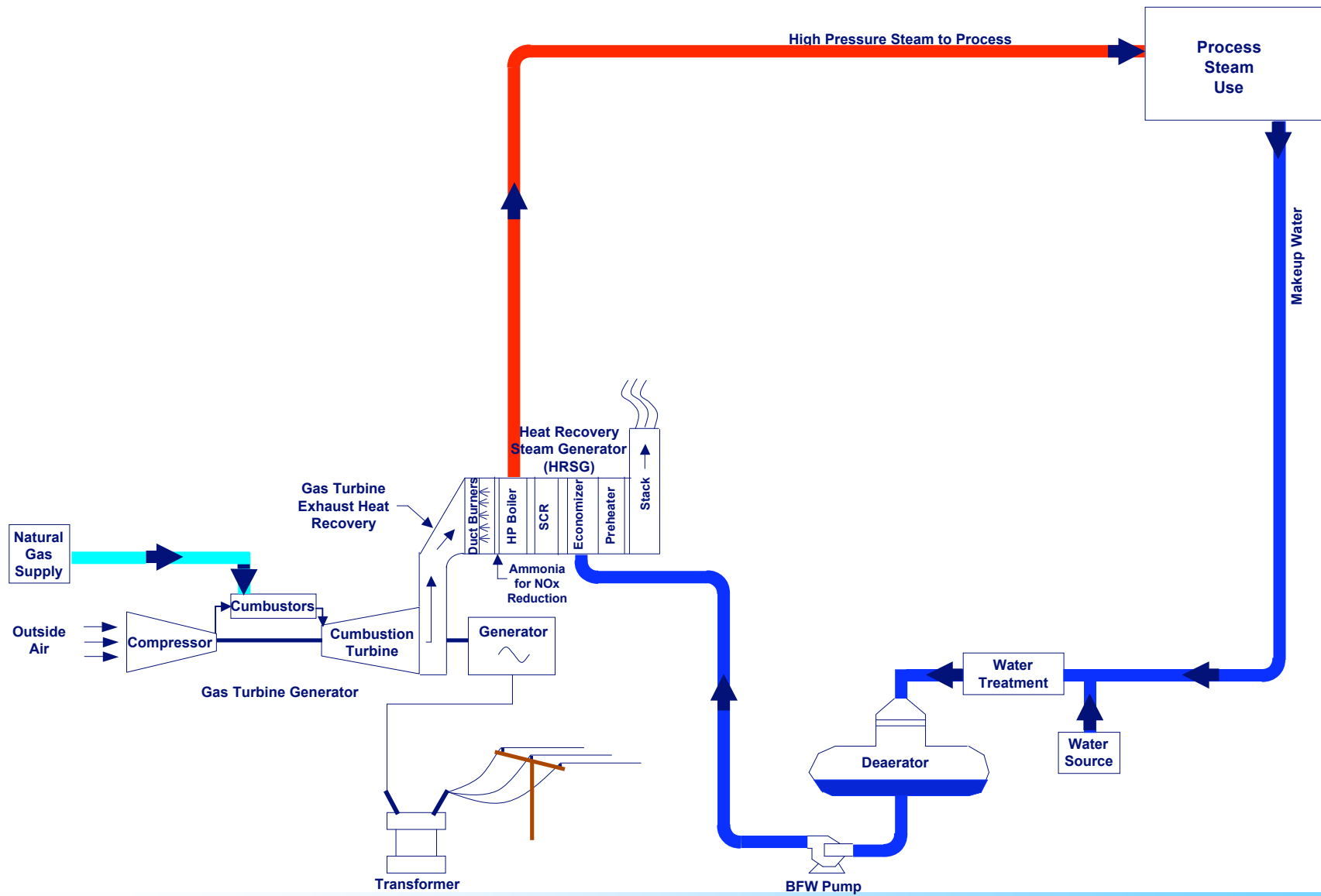
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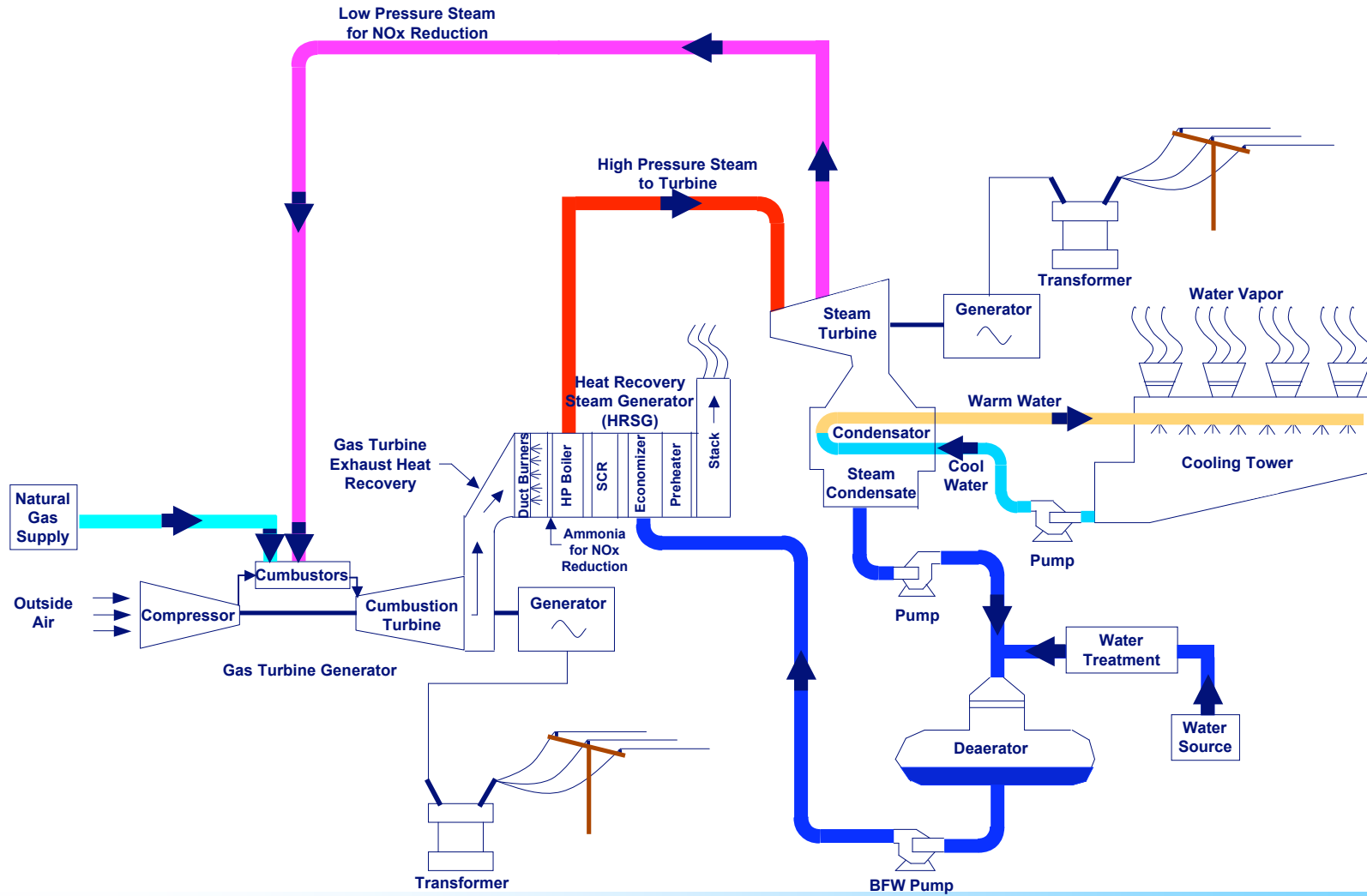
Simple Cycle Cumbustion Turbine



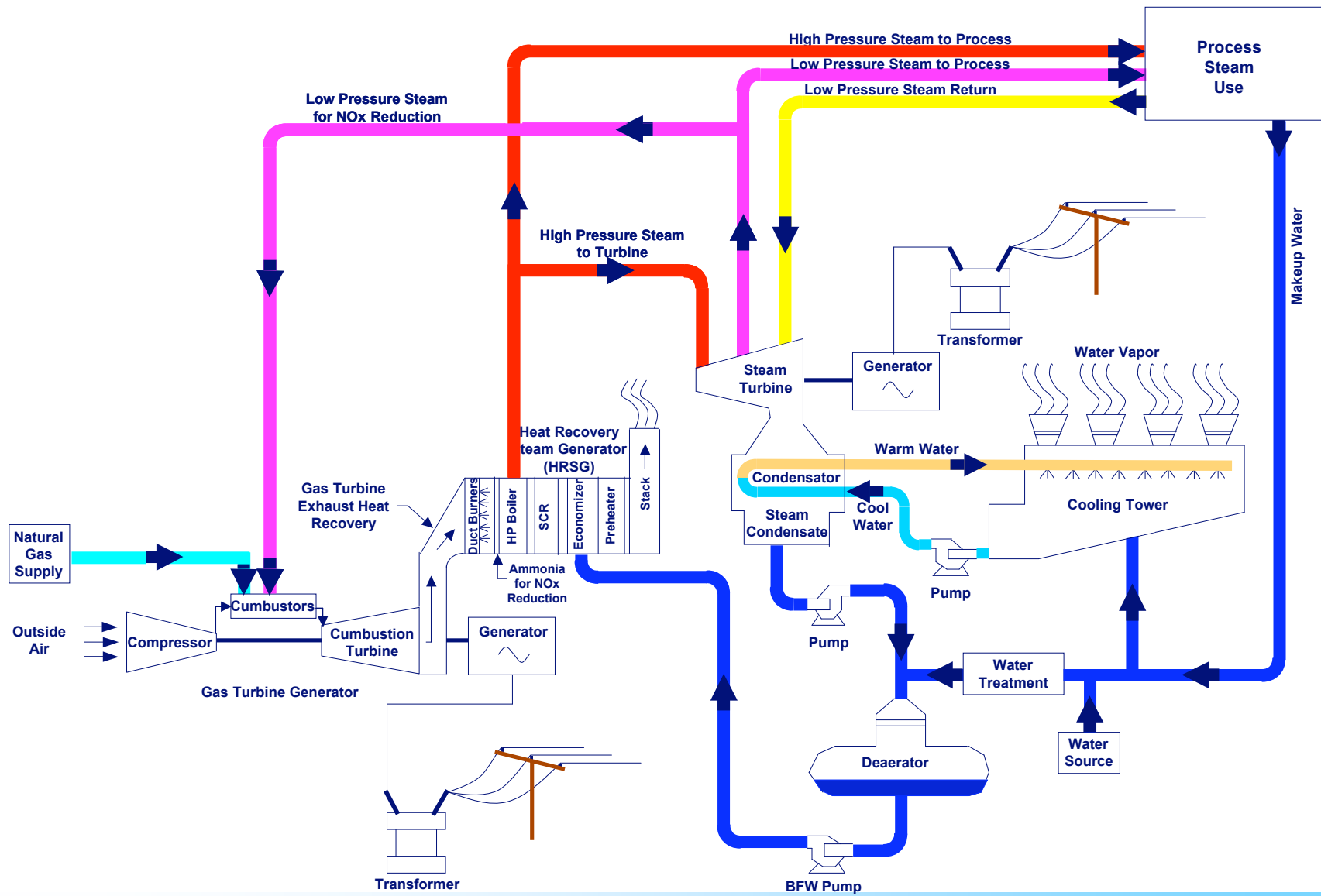
Combustion Turbine Cogeneration



Combined Cycle Combustion Turbine



Combined Cycle Cogeneration



Cogeneration Heat Balance

Inputs:

Fuel Burned in Combustion Turbine

Fuel Burned in Duct Firing

Very Low Pressure Steam returned from Process

Output:

Steam Produced in HRSG

Uses of Output:

High Pressure Steam to Process

High Pressure Steam to Turbine

Low Pressure Steam to Process

Low Pressure Steam to NO_x Control

Sample Cogeneration Facility

Combustion Turbines	two MS5001PA
Combustion Turbine Generation – base rating	25.81 MW each
Combustion Turbine Generation – supplemental fired	25.29 MW each
Combustion Turbine Fuel Use	349.0 MMBtu/hr each
Exhaust Temperature	916 °F
Unfired Steam Production at 400psig	124,000 lbs/hr
HRSB Duct Fired Fuel Use	225.9 MMBtu/hr
HRSB Duct Fired Steam Production at 400psig	310.0 MMBtu/hr
Steam Turbine Generation	35.0 MW nominal
400psig Steam Required by Process	200,000 lbs/hr
Steam Required for NOx Control	30,000 lbs/hr

Calculation of Heat Balance

HRSG Unfired Steam Production (lbs/hr)	248,000	function of CT fuel burned
Net Enthalpy (Btu/lb)	1,150	function of temp and pressure
HRSG Unfired Steam Production (MMBtu/hr)	286	
NO _x Steam Injection (lbs/hr)	30,000	function of CT design
NO _x Steam Injection (MMBtu/hr)	35	
HRSG Duct-fired Steam Production (lbs/hr)	310,000	function of design and fuel use
HRSG Duct-fired Steam Production (MMBtu/hr)	377	
High Pressure Steam to Process (lb/hr)	200,000	process requirement
High Pressure Steam to Process (MMBtu/hr)	231	
High Pressure Steam Used in STG (lb/hr)	328,000	remaining steam
High Pressure Steam to STG (MMBtu/hr)	397	

Enthalpy is the total energy, due to both pressure and temperature, of a fluid or vapor at any given time or condition.

Calculation of Fuel Chargeable to Power

Gross Combustion Turbine Generation (MW)	51	sized to meet heat balance
CT Heat Rate (Btu/kWh)	13,800	design of turbine
CT Fuel Use (MMBtu/hr)	698	
Duct Fuel Use (MMBtu/hr)	226	heat balance requirement
Total Fuel Use (MMBtu/hr)	924	
Total Fuel Use w/o CT (MMBtu/hr)	248	supplies steam requirements using duct firing
Fuel Chargeable to Power	35.6%	$248 \div 698$
Dispatchable CT Heat Rate (Btu/kWh)	4909	$13,800 \times 35.6\%$

Calculations for AURORA Valuation Analysis

Combustion Turbine Minimum Generation

Required Steam Load to Process (lb/hr)	200,000
Fuel Burned to Supply Steam thru CT (MMBtu/hr)	647
CT Generation (MW)	46.9

Combustion Turbine Dispatchable Generation

Incremental Steam Available (lb/hr)	18,000
Fuel Burned to Supply Steam thru CT (MMBtu/hr)	51
CT Generation (MW)	3.7 + 2.1 STG free generation
Dispatchable Turbine Heat Rate (Btu/kWh)	8,790 $51 \div 5.8 _ 1,000$

Steam Turbine Dispatchable Generation

Steam Turbine Generation (MW) balance	29.8 based on heat
Duct Firing (MMBtu/hr)	226
Steam Turbine Heat Rate (Btu/kWh)	7,578 $226 \div 29.8 _$

AURORA Resources Input Table

Non-dispatchable Combustion Turbine

Heat Rate	13800	Must Run	1
Capacity	50580	Min Capacity	100

Dispatchable Combustion Turbine

Heat Rate	8790	Must Run	0
Capacity	3700	Min Capacity	0

Steam Turbine Dispatchable Generation

Heat Rate	7578	Must Run	0
Capacity	29800	Min Capacity	0

AURORA Output

Non-dispatchable Combustion Turbine

Generation (aMW)	50.58	Revenues (\$000)	16309
Fuel Used (000MMBtu)	6114486	Value (\$000)	-3731
Fuel Cost (\$000)	18386	Dispatch Cost (\$/MWh)	42.95

Dispatchable Combustion Turbine

Generation (aMW)	2.40	Revenues (\$000)	842
Fuel Used (000MMBtu)	185175	Value (\$000)	225
Fuel Cost (\$000)	557	Dispatch Cost (\$/MWh)	27.74

Steam Turbine Dispatchable Generation

Generation (aMW)	23.31	Revenues (\$000)	7909
Fuel Used (000MMBtu)	1547142	Value (\$000)	2664
Fuel Cost (\$000)	4652	Dispatch Cost (\$/MWh)	24.06

Reference Articles

Cogeneration Application Considerations

Robert W. Fisk & Robert L. VanHousen

GE Power Systems

http://www.gepower.com/publications/en_us/pdf/GER3430f.pdf

Heat Recovery Steam Generators

Jim McArthur

Innovative Steam Technologies Ltd.

http://www.otsg.com/media/tech_downloads/OTSG_EPIC_paper.pdf