Novel Plasticizer for IM Compliant Solid Propellants

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Acknowledgement of Support and Disclaimer

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Physical Sciences Inc.

VG07-159-1

- **35 year-old company of 175 talented scientists, and engineers**
- **We work in headquarters in Andover, MA, with five satellite locations in the United States**
- **Acoustics**
- **Electro-magnetics**
- **Fluid physics**
- **Life sciences**
- **Chemical sciences**
- **Energetic Materials**
- **Optical sciences**
- **Plasma physics**
- **Space physics**

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NF1 Plasticizer Background

- **NF1 was identified through modeling and literature data as an insensitive propellant ingredient**

  - NF1 will be a liquid at room temperature

  - Potential High Density

  - Improved properties over Butyl NENA

  - IM Capability

NF1 Background (Cont'd)

- **PSI synthesized and characterized (FT-IR, NMR, Elemental Analysis, GC-MS) NF1**
  - Low cost precursors
  - 30% overall yield (not optimized)

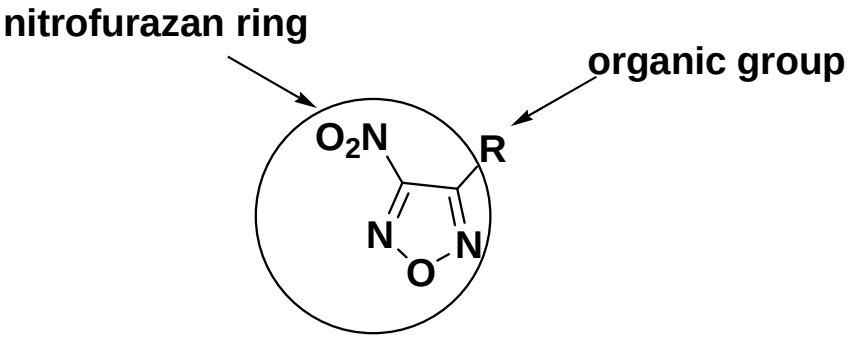
- **Aerojet performed the energetic and thermal properties testing**

NF1 Structure

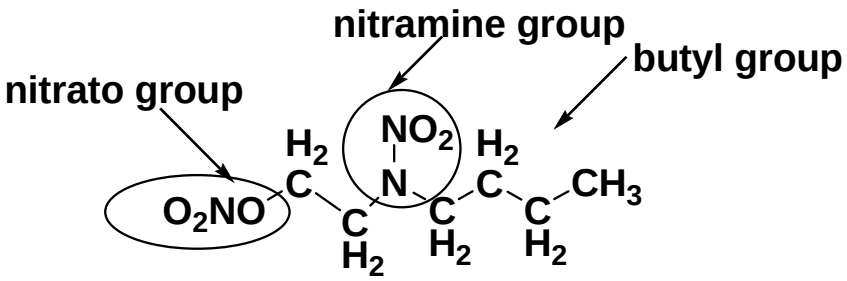
VG07-159-4

- **Structure: Nitro-furazan derivative**

- **Attributes:**
  - only one nitro group: insensitive
  - heterocyclic ring: good density



MF plasticizer



Butyl NENA plasticizer

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NF1 Properties

	Density Gm/cc	Decomposition Temperature, ºC	ΔHf, Kcal/mol
NF1 theor	**1.620**	**180**	**69.5**
NF1 exp.	**1.467**	**180**	**58.8**
Butyl NENA	1.211	165	-45.55
TMETN	1.488	158	-105.8
BTTN	1.520	154	-92.6

NF1 a promising plasticizer with good energy and good density

IM Propellant Approach

- **HTPB propellants exhibit violent cook-off response**
  - Decomposition occurs through ammonium perchlorate decomposition
  - Decomposed AP reacts quickly and violently
- **Energetic additive can reduce AP decomposition violence**
  - Butyl NENA based HTPE formulations generally benign
- ***NF1 can be used as an energetic additive***
  - Reduced energetic groups compared to other additives
  - Energy stored in furazan ring structure
  - Good density due to compact furazan ring

NF1 used as a plasticizer:
Propellant IM Compliance is expected to increase

NF1 Sensitivity

VG07-159-7

- **NF1 properties**
  - Low viscosity fluid
  - Moderate volatility
- **Measurements show it is insensitive**
  - Category “Green” [normal]
- **Insensitive in shock tests**
  - Negative at zero cards


J-4608

Hazard	NF1	RDX
Impact, kg-cm	145	49
Friction, psi @ drop angle, º	1800 @ 90º	1200@90º
ESD, J @ 5kv	6.0	0.38

Negative at highest settings of test instruments

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NF1 Shock Test

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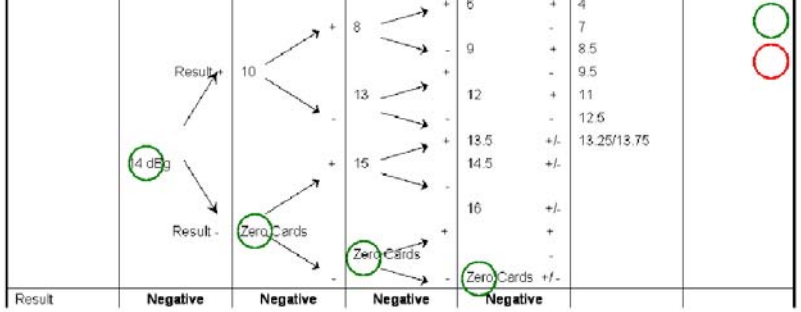
- **Measures shock sensitivity of material**
  - Calibrated to identify threshold sensitivity level
- **Results:**

Program:	PI SBIR	Originator:	S Dawley
Propellant Type:	Nitrate Ester	Charge Number:	38-6672-10-0001
Batch #:	MFNO	Date:	June 13, 2006

Material Hazard/Sensitivity Classification:		Compatibility Group:	Toxicity:
Class 1.1	Green (Normal)	Normal Composite	Normal
Class 1.3	Yellow (High)	Nitrate Ester	Other: Unknown
Other:	Red (Very High)	Other: Experimental Material	

Shot	1	2	3	4	5	6
Tube #						
Result	Negative	Negative	Negative	Negative		



Material is insensitive to shock in the SSGT

J-5048

Sample Loading

Results - *Insensitive*

Material does not detonate even at zero cards

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NF1 Density

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	MF		D.I. H_20
	g/cc		g/cc
	1.4820		1.0156
	1.4884		1.0224
	1.4920		1.0120
	1.4864		1.0168
	1.5004		1.0116
	1.4876		1.0132
	1.4912		1.0176
	1.4944		1.0192
	1.4920		1.0168
	1.4972		1.0152
AVG	**1.4905**	**AVG**	**1.0161**
STDEV	**0.0052**	**STDEV**	**0.0035**
CV	**0.35%**	**CV**	**0.34%**

Density calibration with de-ionized water, correction factor 0.984

Density measured to be 1.467 gm/cc (corrected)

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NF1 Purity

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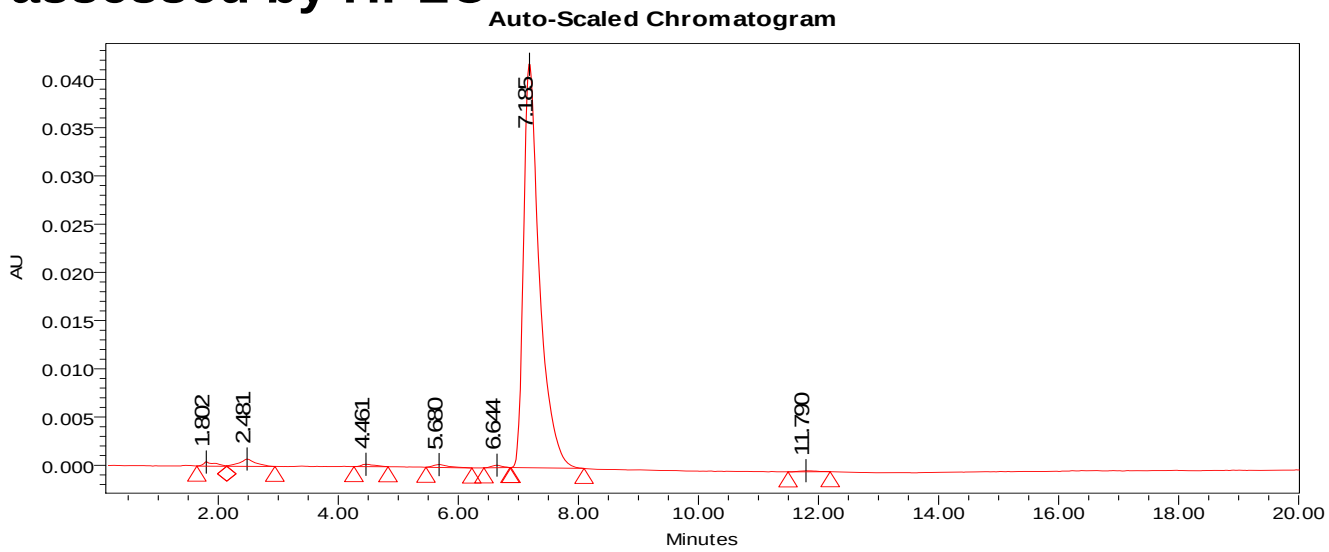
- **Purity assessed by HPLC**



Peak Results

	Name	RT	Area	Height	Amount	Units
1		1.802	6114	436		
2		2.481	13646	746		
3		4.461	4110	246		
4		5.680	5419	297		
5		6.644	3088	257		
6		7.185	771321	41989		
7		11.790	2310	116		

Good purity noted with only minor impurities

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NF1 Volatility

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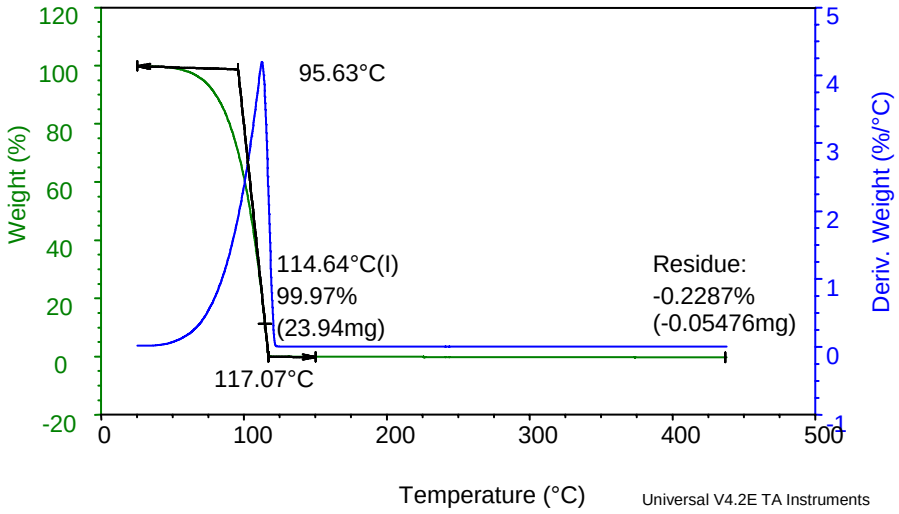

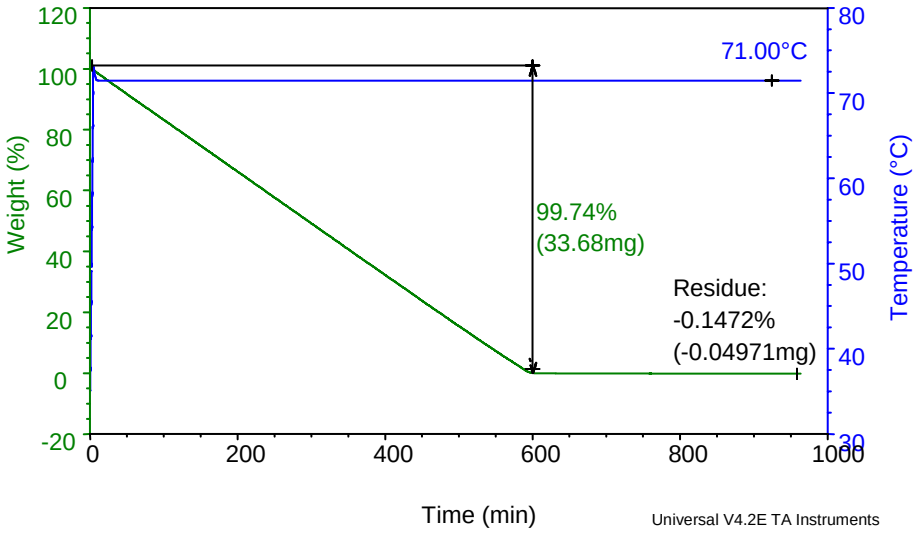

Onset of weight loss in TGA occurs at a low temperature

Isothermal TGA shows material evaporates after 10 hr at 70°C

Chemical modification to NF1 will be required to eliminate volatility

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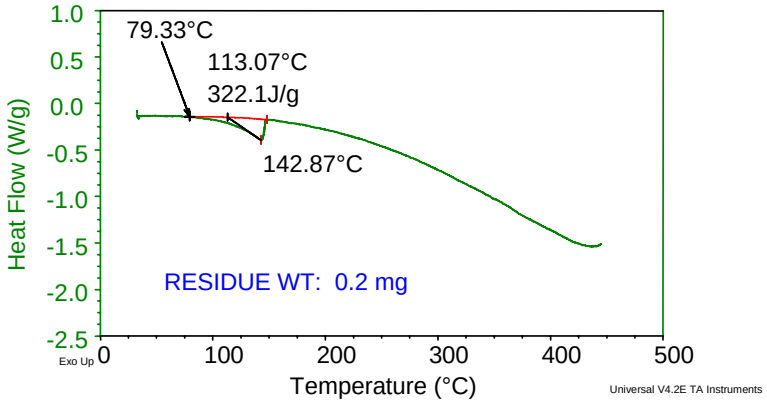
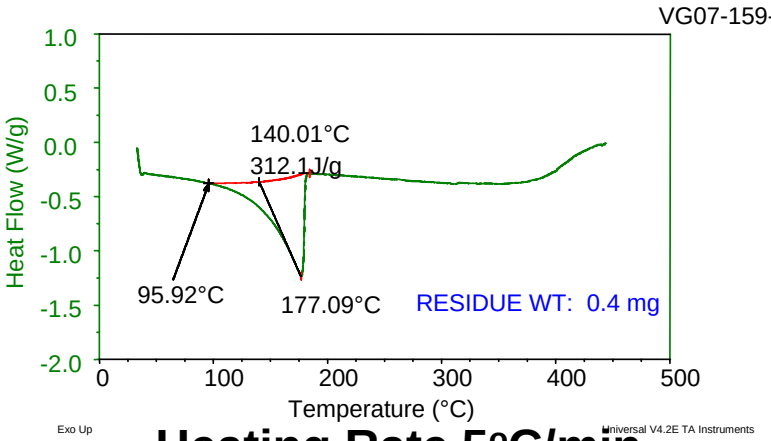
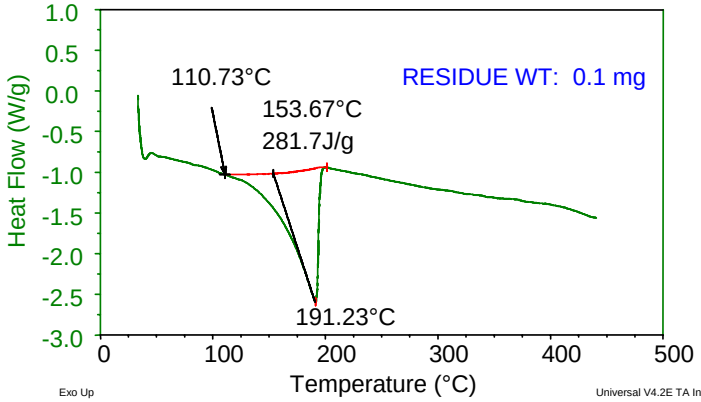
NF1 Differential Scanning Calorimetry



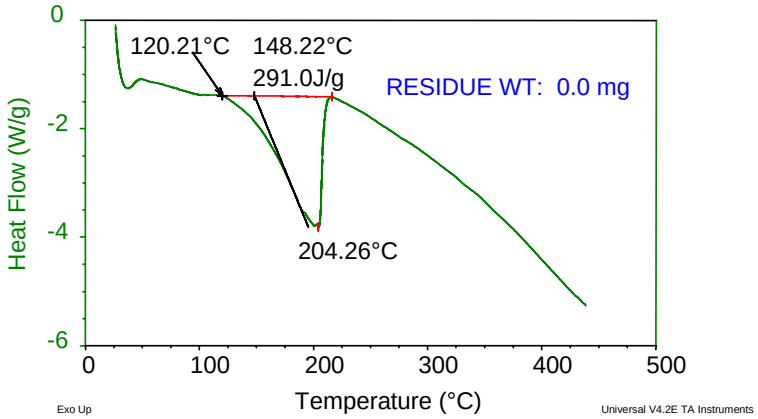
Heating Rate 1°C/min



Heating Rate 5°C/min



Heating Rate 10°C/min



Heating Rate 20°C/min

Endotherm likely due to vaporization – no exotherm noted

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NF1 in a Propellant

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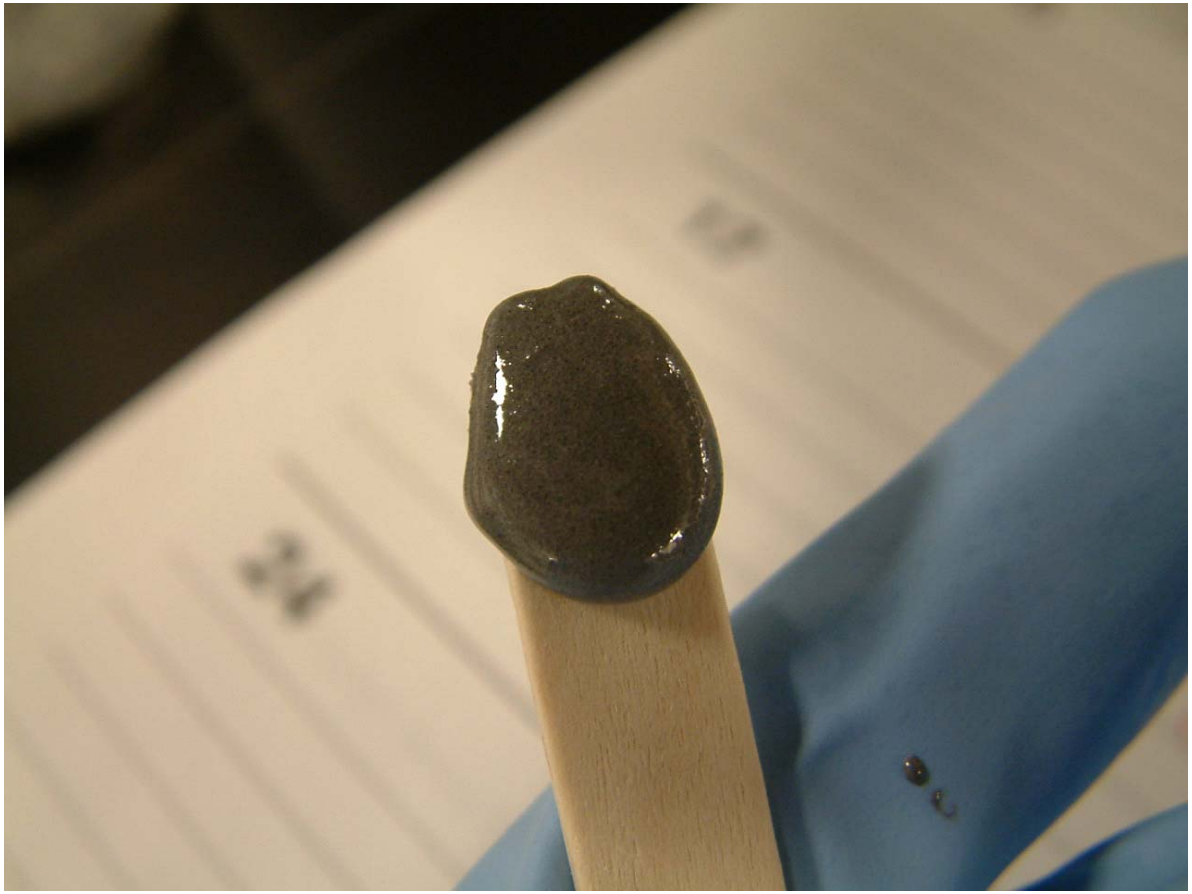

Experimental NF1 propellant prepared for sensitivity testing

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NF1 Sensitivity

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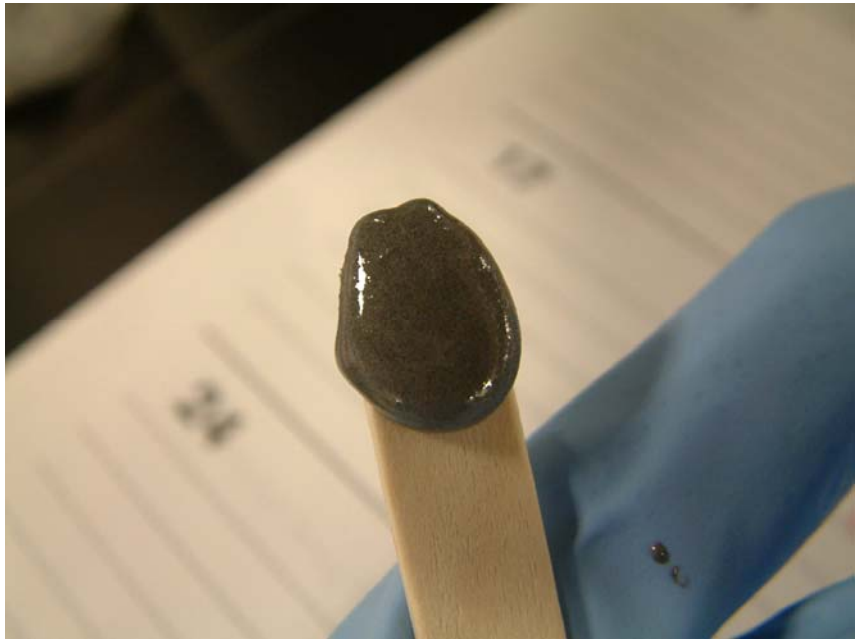
- **NF1 propellant**
  - Small sample prepared
  - Stability evaluated
  - Sensitivity evaluated
- **Sensitivity measurements**
  - Category “Green”
  - Acceptable for scale-up



Hazard	NF1 Propellant	RDX
Impact, kg-cm	100	49
Friction, psi @ drop angle, ^{o}	1300 @ 90^{o}	1200@90^{o}
ESD, J @ 5kv	3.0	0.38

Propellant registers in the normal category for sensitivity

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Conclusions

- **NF1 has been successfully synthesized and characterized in a 30% overall yield**
- **NF1 synthesis used low cost precursors and was produced in high purity (>97%)**
- **NF1 Testing Results: insensitive (“green” category material) both neat and in a propellant formulation**
- **NF1 showed moderate volatility and it needs to be corrected by chemical modification**

Acknowledgments

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