Knowledge Orchestration in Evolving Production Systems

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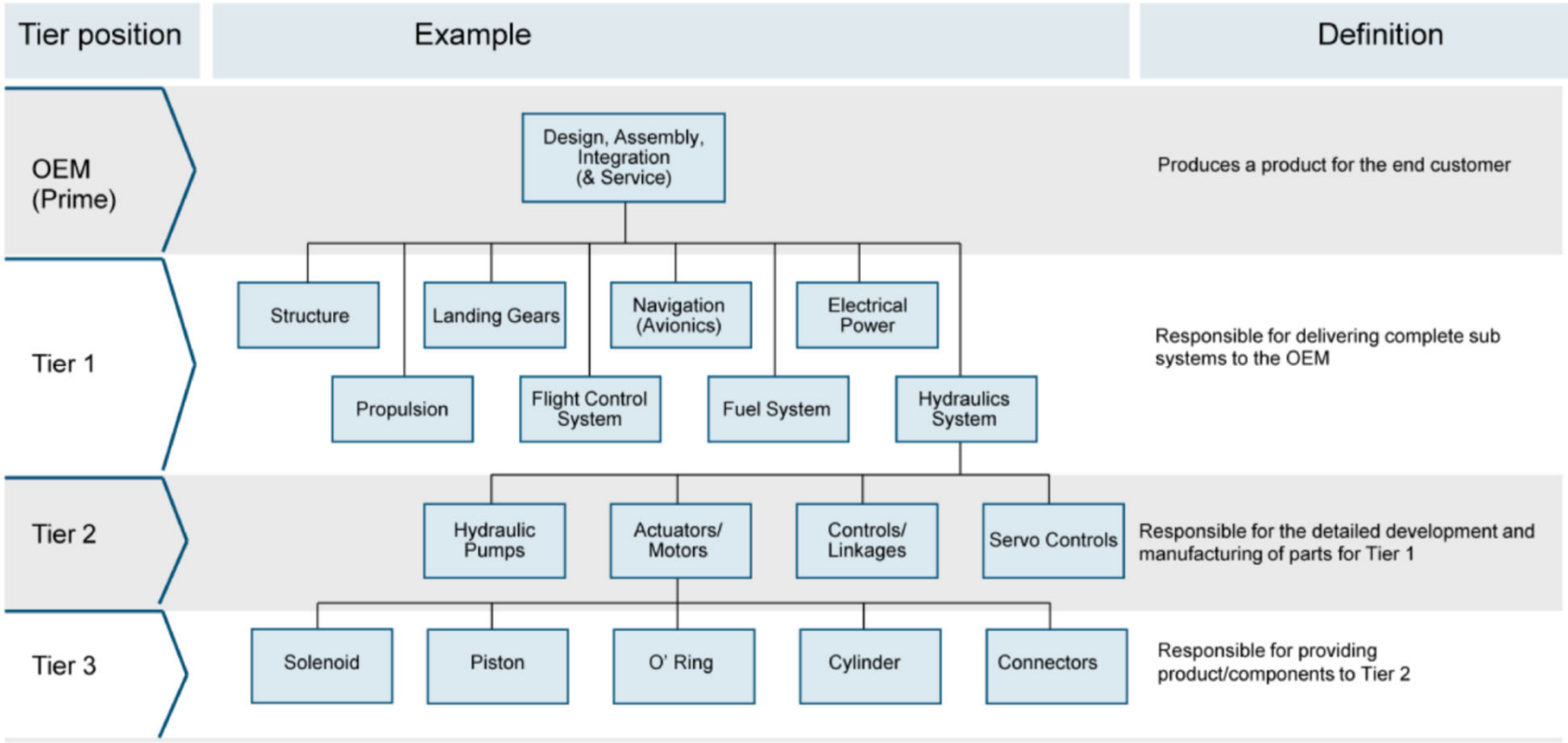
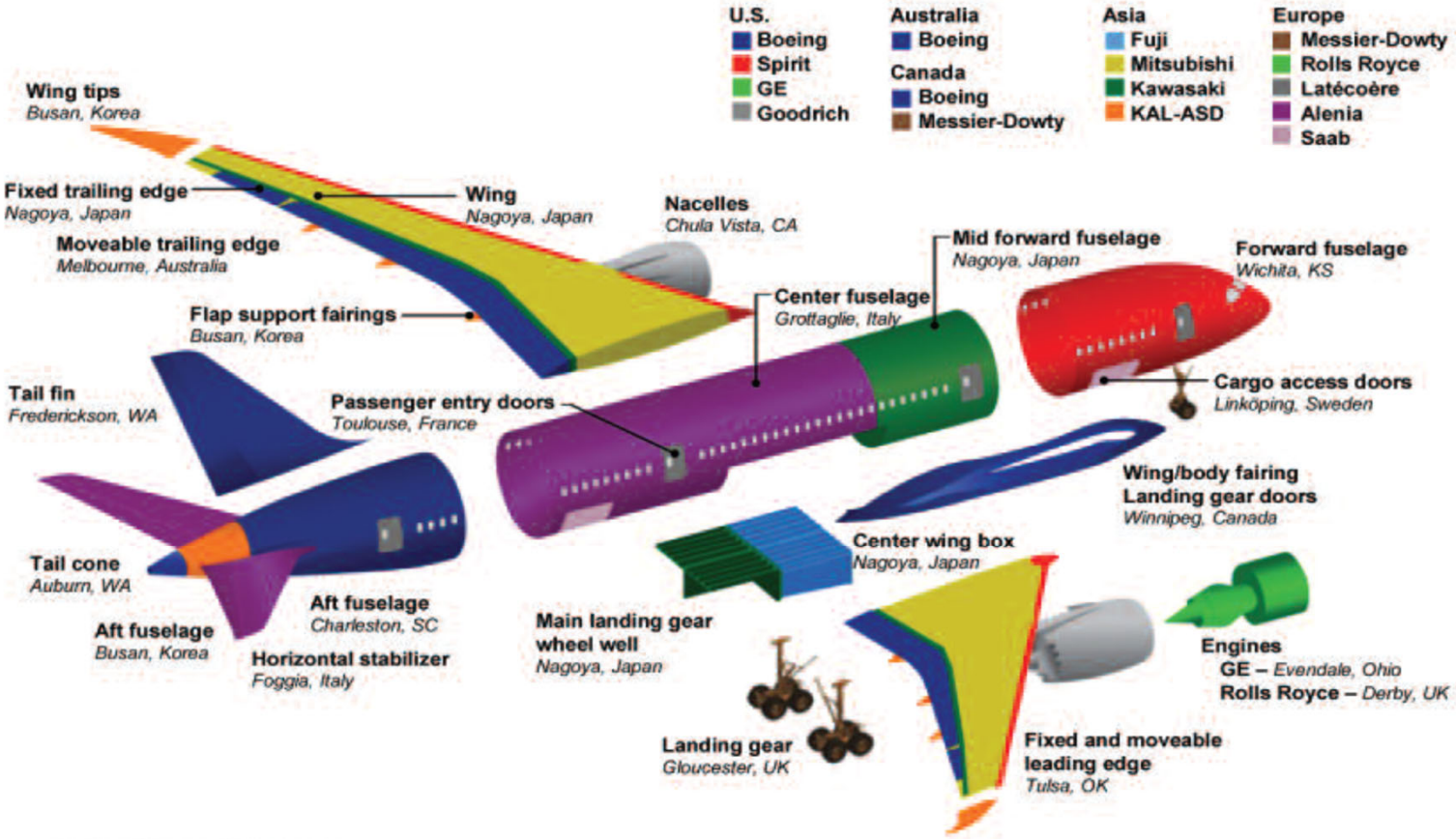
Tier structure



Globalization of value chains



Horizontal consolidation

Table 1.1: Number of suppliers on selected platforms and systems

Airbus		Bombardier		Embraer		Rolls-Royce	
A330 (1994)	A350 (2014)	CRJ (2001)	C Series (2013)	E145 (1996)	E190 (2004)	Trent 500 (2002)	TrentXWB (2014)
150	70	130	30	350	< 40	250	< 50

Open questions

- How do firms source and integrate knowledge in complex production systems?
- Does it differ across production tiers?
- Has it changed as complex production systems have evolved?
- Does all this matter for a firm's innovation performance?

Systems Integration Literature

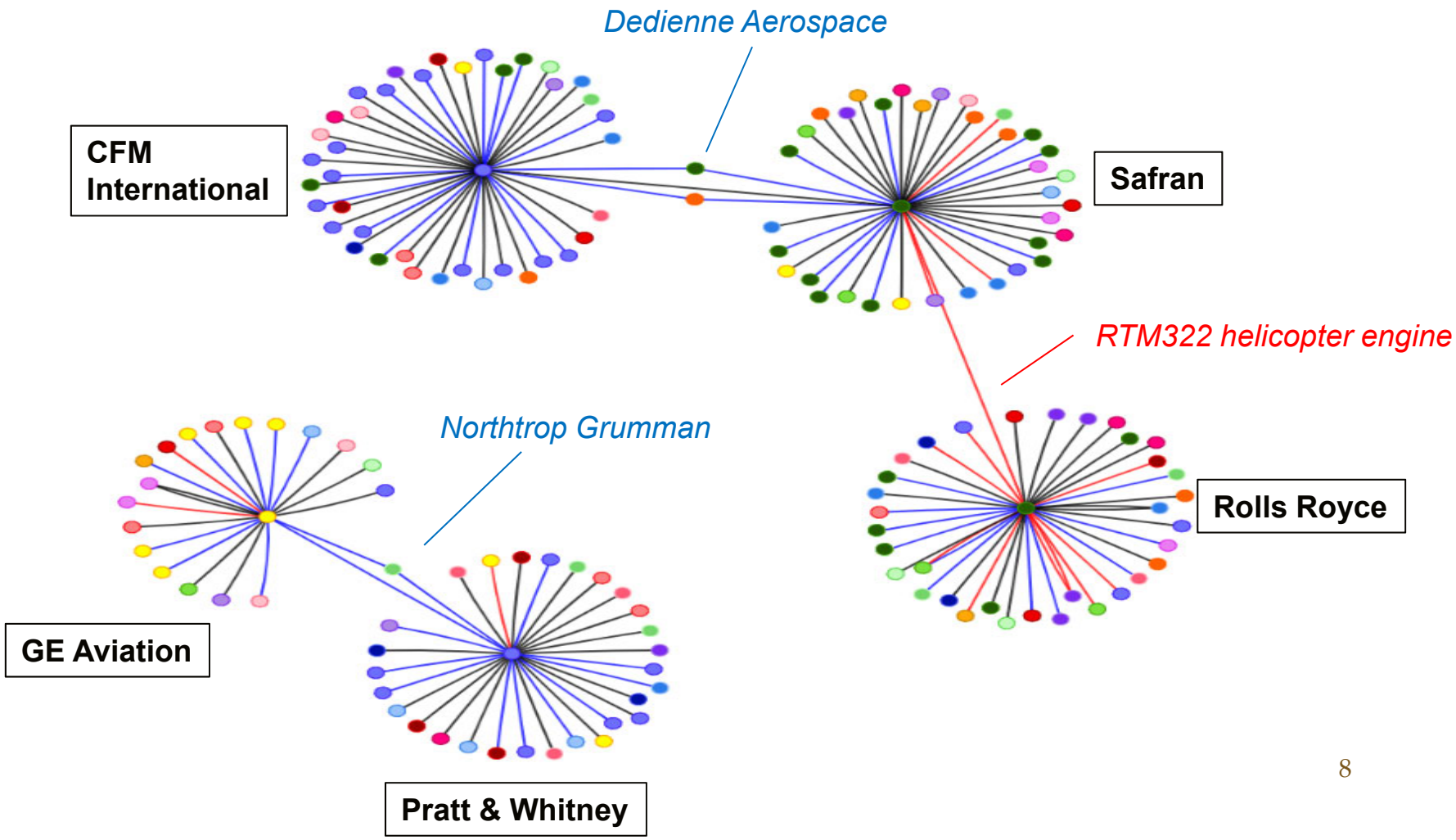
- Who is responsible for integrating knowledge across complex production systems?
- Paradox of modularity (Sanchez & Mahoney 1996; Hoetker 2006; Cabigiosu & Camuffo 2012)
  - Modularity in design reduces firm interdependence
  - Modularity increases need for knowledge sharing to resolve architectural bottlenecks
- As lead firms in the network, system integrators need to know more than they make (Brusoni et al., 2001).
- "Technological scope widening" not limited to systems integrators, but also to component specialists (Di Biaggio 2007, Ethiraj 2007).

➡ A firm's technological diversity and its innovation performance are a function of the firm's position in a complex production system.

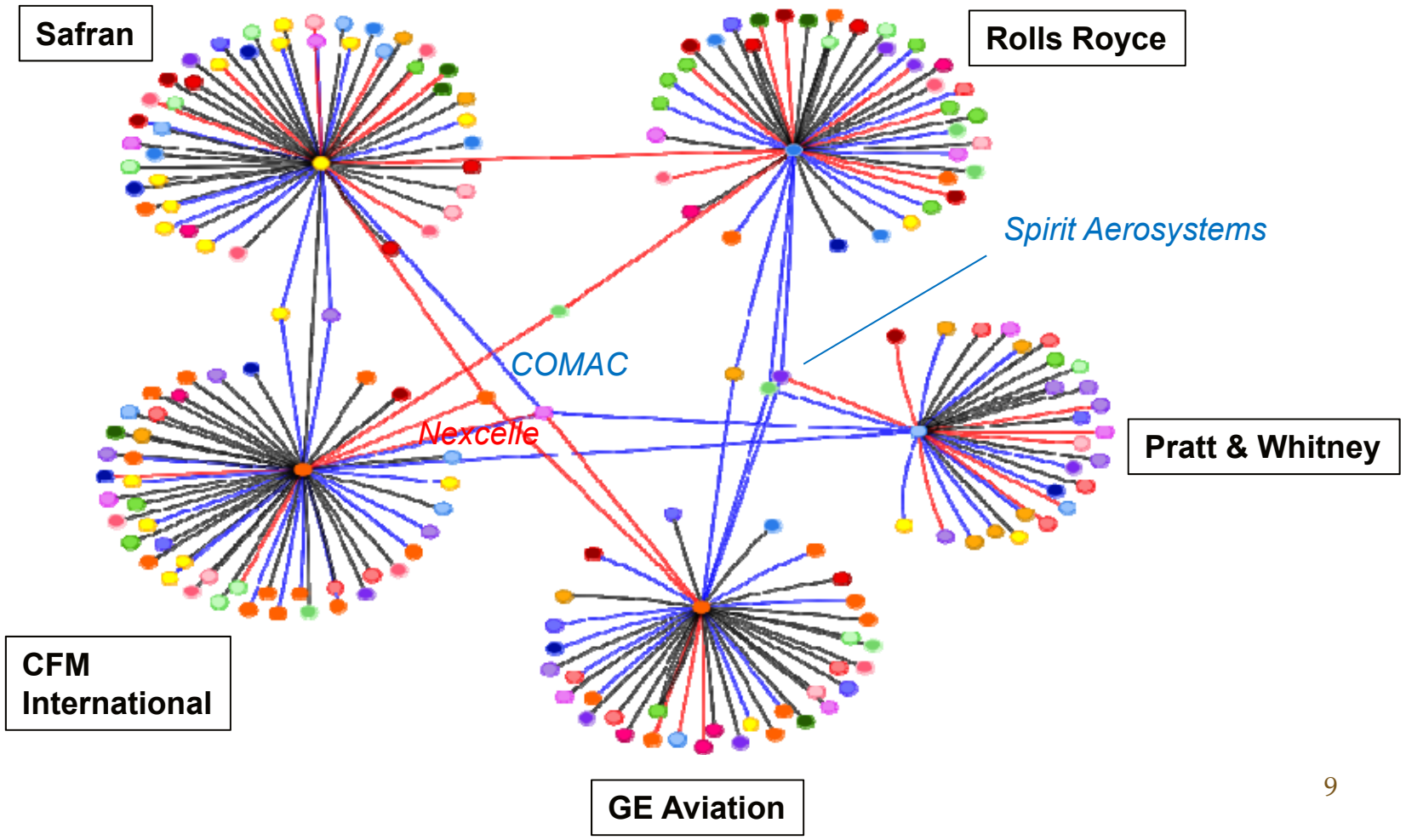
Data description

- Network data:
  - *Five integrators:* CM International, GE Aviation, Pratt & Whitney, Rolls-Royce, Safran
  - Map network linkages with suppliers, buyers and partners during three periods: 2002-2005, 2006-2009, 2010-2014
  - Distinguish between subsidiary, buyer-supplier and partnership linkages
- Firm attributes: Orbis
- Patent data: information on 280,093 patents

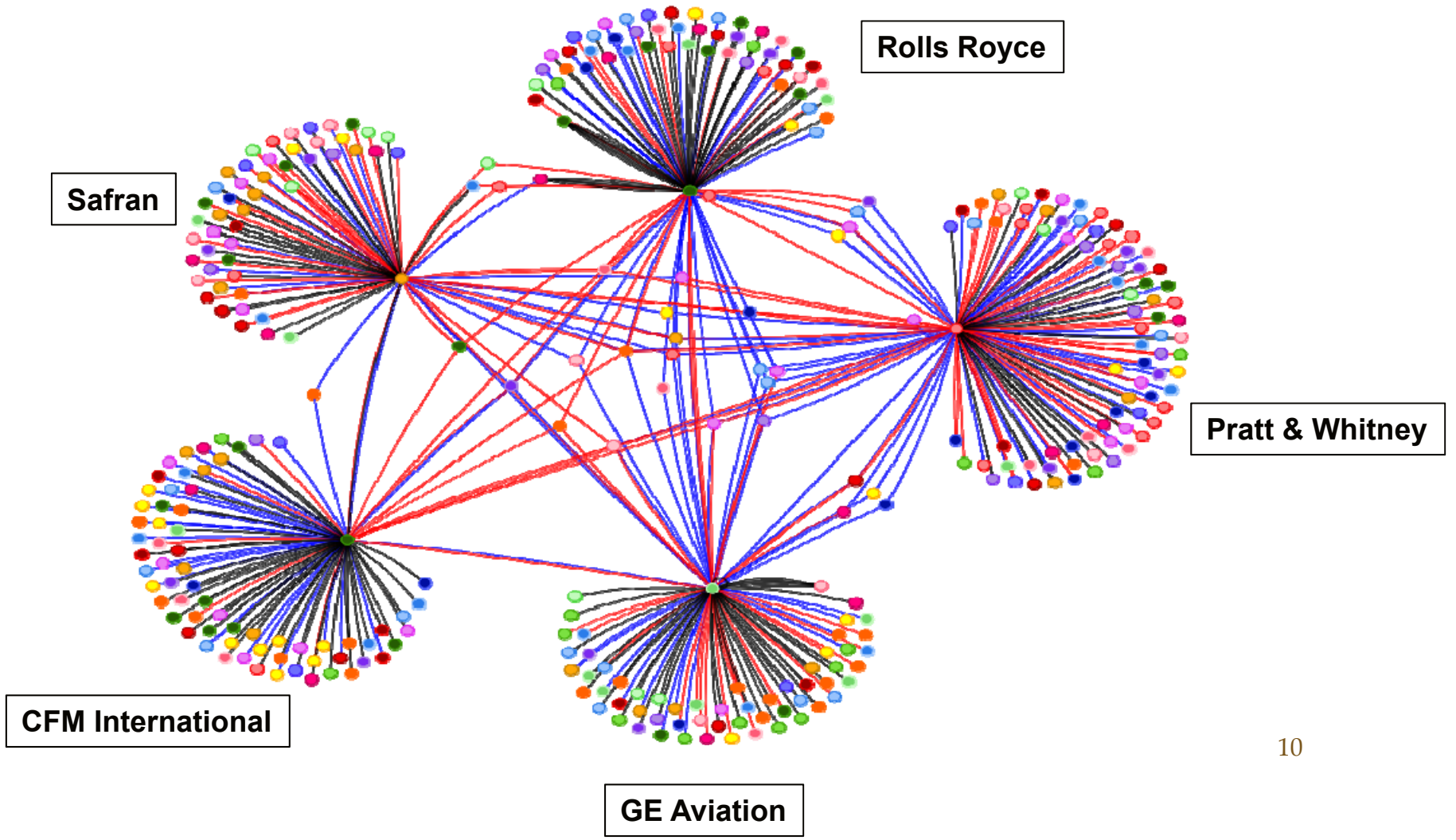
Aircraft engine network 2002-2005



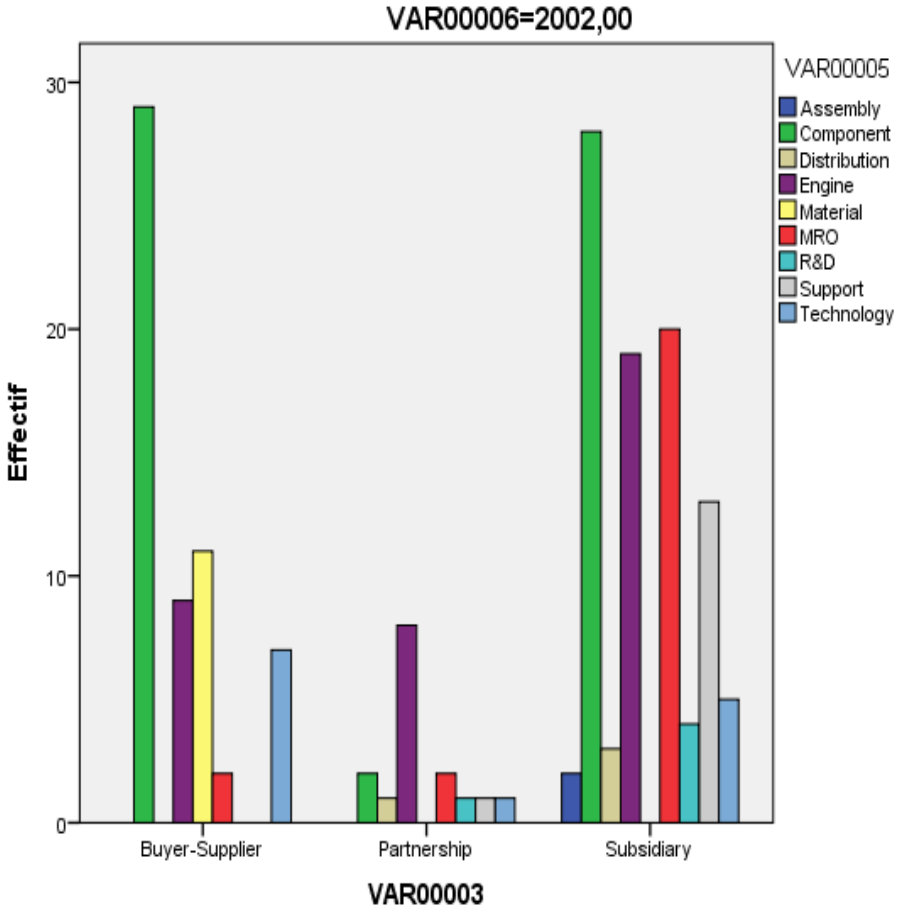
Aircraft engine network 2006-2009

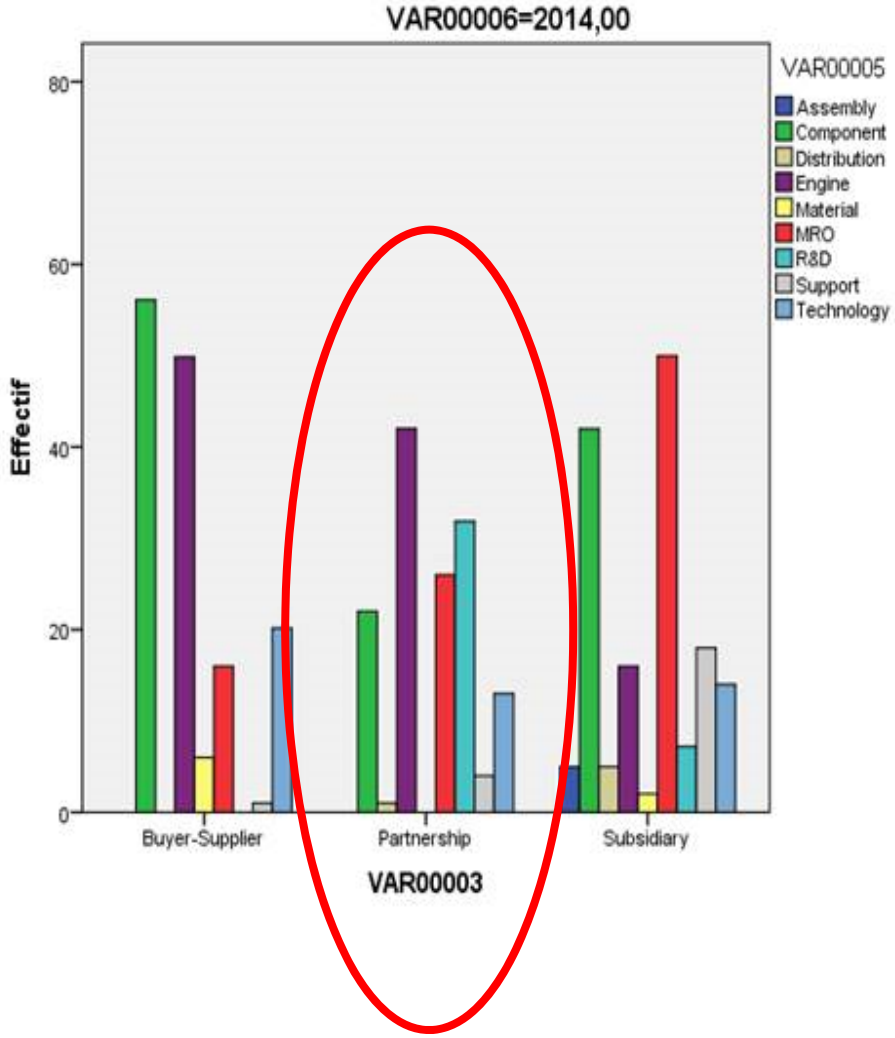


Aircraft engine network 2010-2014



Growing importance of partnership linkages, and especially in R&D





Multi-level analysis – dependent variable: forward patent citations

Variables	Patent level	Firm level	Location level	All levels
Patent co-authorship	0.96*** (0.023)			0.79* (0.61)
Patent co-authorship (different countries)	1.14*** (0.066)			2.27*** (0.28)
Patent co-authorship (different countries)*integrator	0.55*** (0.013)			0.32*** (0.009)
Different technological codes	0.72* (0.67)			0.93** (0.47)
Different technological codes*integrator	0.49*** (0.008)			0.29*** (0.006)
Prevalent type of relationship in the network (buyer-supplier, partner or subsidiary)		0.6 (0.9)		0.8 (0.9)
Tie diversity		4.15 (2.07)**		2.53 (1.05)**
ROE		3.08 (2.01)**		1.13 (1.02)*
Cash flow		1.12 (1.16)		1.46 (1.52)
Network eigenvector centrality(FIRM)		2.81 (0.55)***		1.05 (0.34)***
Network eigenvector centrality(LOCATION)			0.81 (0.25)***	0.63 (0.64)
Size		7.3 (2.42)***		6.9 (2.55)***
Location specialization			1.02 (1.01)*	0.85 (0.85)
Location specialization in R&D			1.99 (1.85)**	1.41 (0.93)**
Economic development			1.01 (1.07)	1.26 (1.28)
Wald Chi-square	21.86***	36.07***	44.92***	20.93***
Δ Deviance	8.009	10.738	11.997	7.829
AIC	453.026	621.935	717.904	428.575
BIC	612.301	799.011	848.186	607.022
Variance explained	*14%*	*26%*	*9%*	*42%*
N	*280093*	*288*	*53*	*280093*

Notes: ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively. Patent, firm and location fixed effects included.

Interpretation

- In a complex production system, innovation performance (measured by forward patent citations) is positively related to both the technological and location diversity into which firms tap.
- The positive relation is stronger for systems integrators than for component specialists.
- Both network position and location in R&D hot spots are positively related to innovation performance.

Negative binomial analysis

Variables	Technological diversity (# technological codes a firm filed per time period)	Patent authorship (# collaborating countries per time period)
Integrator	2.64 (1.38)***	2.12 (1.22)***
Partnership ties	0.41 (0.46)	0.16* (0.14)
Tie diversity	1.83 (1.02)**	1.53 (1.53)
ROE	3.58 (2.01)**	2.07 (0.64)***
Cash flow	1.02 (1.11)	1.96 (2.09)
Network eigenvector centrality	3.09 (0.75)***	3.91 (0.84)***
Size	2.15 (0.71)***	4.28 (1.62)***
Firm fixed effects	yes	Yes
N	288	288
Chi2	784.22***	825.12**
Log likelihood	-1294.08	-1315.27

Note: ***, ** and * denote significance at the 1%, 5% and 10% level.

Interpretation

- In a complex production system, technological diversity is positively related to a firm's size, tie diversity and network centrality.
- Integrators have a higher technological diversity and collaborate more across countries than component specialists.

Conclusion

- A firm's position in a complex production system matters for both the diversity of its knowledge base (technological diversity) and its innovation performance.
- Systems integrators have a larger technological and collaborative scope, which allows them to more efficiently make decisions on what to source, from whom to source, and how to effectively integrate these technologies into the system.
- Their technological diversity, in turn, strengthens their innovation performance.